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Environmental Assessment

Waste Treatment Facility

OWMC
Ontario
Waste Management
Corporation

A provincial crown corporation.

OWMC TREATMENT FACILITY
PROCESS AREA REPORT
SOLIDIFICATION

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Attention: Mr. R. V. Griffiths
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Gentlemen:

OWMC Treatment Facility
Monenco Contract No.: MNC 8084-2

Process Area Report - Solidification

We are pleased to submit herewith the draft report entitled: Process Area Report - Solidification. The report describes the rationale for the selection of technologies including the conceptual design of the solidification plant of OWMC's proposed Facility for the treatment and disposal of liquid industrial and hazardous waste in Ontario.

We trust that this report meets the Corporation's requirements.

Yours very truly,

J. V. Fitzgerald
Project Manager

RV/jj

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EXECUTIVE SUMMARY

PURPOSE OF THE REPORT

This report describes the rationale for the selection of technologies included in the conceptual design of the solidification plant of OWMC's proposed Facility for the treatment of liquid industrial wastes and hazardous wastes.

The background and rationale for including solidification of inorganic treatment residues in the design of OWMC's Facility has been presented in earlier reports (Ref: The Proctor & Redfern Group[2], OWMC[3]). The choice of rotary kiln incineration, physical/chemical treatment, solidification and an engineered landfill as the four major components of the Facility was subsequently confirmed in the report entitled "Rationale for the Selection of Technologies for the Treatment and Disposal of Special Wastes in Ontario" - July 1985 (Ref: A. D. Little of Canada Limited[4]).

Therefore, this report focuses on the alternative technologies which can be included in the solidification plant for the treatment of inorganic residues prior to disposal in the engineered landfill. The report describes the alternative technologies considered, the methodology used to compare and evaluate them and the results of technology selection. The report also describes how the selected technologies have been combined into solidification systems and outlines how the complete systems have been optimized to maximize the performance, safety, flexibility and reliability of the solidification operation.

This process area report on solidification is one of five such reports which together cover all areas of the proposed OWMC treatment Facility. Process area reports for incineration, physical/chemical treatment, engineered landfill and general facilities are contained in separate companion reports (Ref: Monenco Limited[5,6,7,8]). The Facility Description Report (Ref: Monenco Limited[9]) provides a complete description of the proposed Facility, including a discussion on the effluents and emissions discharged from the Facility.

This report was prepared for OWMC by Monenco Limited, who are also responsible for preliminary engineering of the overall Facility. Technical input to this report was provided by Mr. J. R. Conner, formerly of Chem-Technics, Inc. of Atlanta, Georgia and now with Conner Technologies, who is the specialist consultant for the solidification plant.

It is important to appreciate from the outset, the contribution which solidification will make as part of a treatment philosophy, in ensuring that OWMC's Facility can treat Ontario's special wastes in a safe manner which will minimize risk to human health and impact on the environment. This is explained below:

At OWMC's proposed Facility, inorganic wastes will be treated by the physical/chemical processes and organic wastes will be destroyed by incineration. The primarily inorganic residues from the above mentioned processes, together with selected residues from waste generators, will be treated by the solidification processes before being disposed of in an engineered landfill.

SCOPE AND METHOD

A systematic approach was used to evaluate alternative technologies and select a preferred combination of technologies that will satisfy the treatment objectives of solidification. The selected solidification technologies were then incorporated in the conceptual design of the solidification systems and the systems optimized to ensure that OWMC's goals of minimizing risk to human health, impact on the environment and cost are achieved in a satisfactory manner.

The following points summarize the approach adopted and methodology employed:

- Establish the major treatment objectives and key treatment philosophies for solidification.

- Establish criteria for technology selection.

- Prepare a "long list" of possible solidification technologies.

- Establish a "short list" of potentially suitable technologies from the "long list" of technologies, by eliminating technologies that are not proven, or not suitable for OWMC's Facility.

- Define specific process requirements for solidification and list alternative technologies which are potentially capable of meeting these objectives.

- Evaluate and rank the relative suitability of each technology according to the established criteria and select one or more preferred technologies for inclusion in the conceptual design.

- Design and optimize the resulting solidification systems to satisfy the treatment objectives and treatment philosophies established for solidification.

PREMISES AND POSTULATES

OWMC has developed the following basic planning principles and guidelines which are central to technology selection and process design in all areas of the proposed Facility including the solidification plant.

- Wastes must undergo treatment to the fullest extent possible, using the best available proven technologies, prior to the safe disposal of the remaining treated residues.

- It is the Corporation's goals to:
  - minimize risk to human health,
  - minimize environmental impacts, and
  - minimize financial costs to OWMC and the people of Ontario.

The following additional premises provided by OWMC have been used as starting points for technology selection and process design of the solidification plant.

- The solidification plant will be designed to process residues which are inorganic in nature. All organic wastes which are sent to OWMC's Facility for treatment will be destroyed in a rotary kiln incineration plant. The small quantity of treatment residues from the physical/chemical plant which is organic in nature, will be incinerated. Solid and liquid inorganic treatment residues from the physical/chemical treatment and incineration plants will be processed in the solidification plant prior to being deposited in an engineered landfill.

- The solidification plant will be designed for an initial capacity to process residues from 120 000 t/a of inorganic special wastes and 30 000 t/a of organic special wastes delivered to OWMC's Facility.

- The solidification plant will be initially operated one shift of 8 hours per day, 5 days per week and 50 weeks per year, to process residues resulting from 50 000 t/a of inorganic special wastes and 20 000 t/a of organic special wastes delivered to the Facility.

- Additional shifts will be operated as required to achieve sufficient solidification capacity to process the anticipated quantities of treatment residues, when the Facility is operating at its initial capacity of 150 000 t/a.

- The solidification plant will be capable of expansion to process treatment residues resulting from 240 000 t/a of inorganic wastes and 60 000 t/a of organic wastes delivered to the Facility.

- Space will be provided to enable the solidification plant to be expanded to achieve the ultimate Facility capacity of 300 000 t/a.

- The types and quantities of residues which are expected to require treatment in the solidification plant have been determined taking into account waste data provided by OWMC, and are shown in bold face on Table 1 (p. 7).

- The residue characteristics available are typical of the types and quantities of material which the solidification plant could receive. However, variations may result from:

    - effectiveness of OWMC's 4R program, which is to encourage industry in Ontario to Reduce, Recover, Recycle and Reuse industrial waste,
    - industry's response to market demands and to financial constraints,
    - process and manufacturing changes, and
    - changes in Provincial waste regulations.

- On this basis it is important that the solidification process design incorporate features such as:
  - maximum flexibility,
  - future expansion capability, and
  - reserve storage and treatment capability.

Postulates are assumptions which have been made by Monenco and are basic to the approach used to evaluate alternatives and arrive at optimum systems design. The key assumptions, treatment objectives and treatment philosophies which have influenced technology evaluations and systems design in the solidification plant are summarized below.

- The solidification systems will be designed to achieve the following treatment objectives:

  To process solid and liquid inorganic treatment residues from the incineration and physical/chemical treatment plants, such that the solidified material will:

  - be physically stable such that the solids produced will not revert back to their original liquid or sludge state, i.e. will change only very slowly in the landfill, essentially on the same time scale as natural rocks and minerals, and

  - be chemically stable in that the solidification processes should not only chemically solidify the residues, but also render insoluble, immobilize and otherwise react with the contaminants in the residues, and thereby minimize the rate at which these contaminants will dissolve in water (leaching) due to the infiltration of water into the landfill.

  To process selected residues from waste generator's facilities to the same quality objectives as treatment residues, described above.

To solidify inorganic treated liquid streams from the physical/chemical processes which cannot be discharged from the Facility, for whatever reason, and to the same quality objectives as treatment residues.

To ensure that treatment operations can be carried out safely.

- Solidification will not be applied to hazardous, raw wastes. Such wastes will either be destroyed in the incineration plant or pretreated in the physical/chemical plant to produce residues that will be treated in the solidification plant.

- Technology selection will be directed toward selecting a preferred combination of solidification technologies which are best suited for the range of treatment residues to be processed, recognizing that no single solidification technology is capable of fulfilling all of the process requirements for all of the treatment residues expected.

- The solidification plant will treat all residues in a batchwise fashion. This mode of operation has been adopted to maximize control and effectiveness of the treatment process. Hence, processes must permit individual batches to be treated separately without cross contamination or intermixing.

- Changes and improvements will be made as required throughout the life of the plant to adapt to changing waste profiles and technological improvements and to maintain the efficiency of the system for achieving the best possible treatment.

- Laboratory scale treatability tests will be carried out on samples in advance of solidifying residues in the plant, in order to:

  - ensure that the treatment efficiency will not be adversely affected by blending certain residues prior to or during treatment,
  - select the optimum solidification formulation,
  - determine optimum process conditions, and
  - verify the quality of the solidified material.

- The solidification plant will be designed to process residues in solid or liquid form or in mixtures of solids and liquids ranging from slurries to pastes.

- Based on the broad categories of residues that are candidates for solidification (Section 2.4, Table 1, p. 7), it is evident that there are two predominantly different types of feed to the solidification plant. These are:

  - non-pumpable, high solids content material, and
  - pumpable, low solids content material

  which require different handling and processing methods. Hence, the solidification plant will comprise a high solids content treatment system and a low solids content treatment system.

- The selected design capacity of the solidification system will be capable of accommodating the design flow rate of treated liquid effluent streams from the physical/chemical plant so that these streams can be solidified if, for whatever reason, they are unable to be discharged by evaporation, from the Facility.

STATUS OF DATA

The waste profile developed by OWMC is considered to be typical and wide variations are expected over the operating life of the facility. This has been recognized in the selection of technologies and in the design and optimization of the solidification plant.

In the evaluation of technologies, emphasis has been placed on information and data pertaining to individual technologies that are in the public domain and/or, can be verified.

While a logical and quantitative methodology has been adopted in the evaluation of technologies, qualitative judgement of the specialist consultant on solidification, Mr. J. R. Conner, has been extensively used in the ranking of solidification technologies against the sub-criteria.

Technical input to the design and optimization of the solidification plant has been provided by Mr. J. R. Conner.

MAIN FINDINGS

Portland cement based technologies with minor additives, are the most suitable for the solidification of high solids content residues. Additionally, the capability to utilize Portland cement/lime, Portland cement/clay, Portland cement/flyash and Portland cement/soluble silicate for the solidification of certain specific high solids content residues should be provided.

The Portland cement/soluble silicate technology is the most suitable for the solidification of low solids content liquid residues.

Technical information and data that are available in the public domain are sufficient for the design of the solidification plant.

The solidification plant incorporates the selected best available and proven technologies to solidify the wide range of residues expected. The design has been optimized to provide a high degree of performance, safety, flexibility, and reliability in:

- the receipt and handling of the wide range of material,
- solidifying the material in either the high solids treatment system or low solids treatment system, as appropriate, to the quality objectives stated under premises and postulates,
- its utilization of reagents that are safe to handle, with a long history of industrial use, and hence there is no possiblity of explosion,
- employing controlled reactions between inorganic residues and reagents such that there is no possibility of sudden release of gases to the atmosphere,
- its capacity to solidify materials in widely varying quantities by the inclusion of conservative design margins, multiple process units and installed spare equipment, and
- its capability to solidify treated liquid effluents from the physical/chemical plant for extended periods if the effluents cannot be otherwise disposed of, for whatever reason.

The design also provides for the planned and orderly expansion of the solidification plant to process residues resulting at the ultimate capacity of 300 000 t/a.

The selected technologies for the high solids treatment system and the low solids treatment system consume the lowest quantity of reagents for the solidification of the various residues, compared with other technologies considered, and therefore:

- minimize occupational risk to plant operating personnel by limiting their exposure to dust and noise (these are influenced by the quantity of reagents handled),
- minimize environmental risk by:
  - minimizing truck traffic for the transportation of reagents to the Facility
  - minimizing the quantity of solidified material to be deposited in the landfill and hence limiting land use, and,
- minimize financial costs in terms of limiting the quantity of reagents and landfill volume used.

These characteristics demonstrate how OWMC's goals have been influential in selecting solidification technologies for OWMC's Facility.

The selected technologies will also provide the most effective treatment by immobilizing residual contaminants of concern in the treated residues to the best practical level for the broadest range of contaminants that may be expected in the feed material to the solidification plant. Ample data is available to demonstrate the usefulness of solidification technologies in containing contaminants within the solidified mass, and thereby reducing the concentration of contaminants in the leachate. This is further addressed in Chapter 4, where performance of the solidification plant is discussed.

It is concluded that OWMC's solidification plant will complement the incineration of organic wastes and physical/chemical treatment of inorganic wastes, in ensuring that the solidified treatment residues disposed of in the engineered landfill are both physically and chemically stable. It will ensure that the concentration of residual contaminants present in the landfill leachate is reduced to the lowest possible level, thereby minimizing risk to human health and impact on the environment.

CHAPTER 1

INTRODUCTION

1.1 PURPOSE OF THE REPORT

This report describes the rationale for the selection of technologies for inclusion in the conceptual design of the solidification plant of OWMC's Facility. The report describes the alternative technologies considered, the methodology used to compare and evaluate them and the results of technology selection. The report also describes how the selected solidification technologies have been combined into treatment process systems and outlines how the process design has been optimized to maximize the performance, safety, flexibility and reliability of the solidification operation.

During Phase 2 of the Facilities Development Process, OWMC commissioned a study to compile and review all possible treatment technologies that may be utilized in a central facility for the treatment of liquid industrial waste and hazardous wastes. The results of this study are compiled in a report entitled "Generic Process Technologies Studies" (Ref: The Proctor & Redfern Group[2]).

Following this study, OWMC determined that "The facilities would consist of high temperature thermal destruction, physical/chemical treatment processes including solidification and an engineered landfill." (Ref: OWMC[3]) This choice of systems was subsequently confirmed in the report entitled "Rationale for the Selection of Technologies for Treatment and Disposal of Special Wastes in Ontario" (Ref: A. D. Little of Canada Limited[4]).

This process area report on solidification is one of five such reports which together cover all areas of the proposed OWMC treatment Facility. Process area reports for incineration, physical/chemical treatment, engineered landfill and general facilities are contained in separate companion reports (Ref: Monenco Limited [5,6,7,8]). The Facility Description Report (Ref: Monenco Limited[9]) provides a complete description of the proposed Facility, including a discussion on the effluents and emissions discharged from the Facility.

Chapter 2 of this report summarizes the philosophy adopted by OWMC for the design of this Facility, the types of treatment residues from various process areas and residues from generators that are expected to be treated by solidification, and the basic philosophy, objectives and assumptions (premises and postulates) that have together formed the framework from which the selected solidification processes will be expected to operate.

Chapter 3 then presents the methodology, criteria, results and conclusions of technology evaluation and selection, including the reasons for either accepting or rejecting each of the alternative treatment technologies.

The final chapter of the report describes how the chosen solidification technologies will be employed to form treatment systems. This chapter also outlines the manner in which the process design has been optimized to maximize the performance, safety, flexibility, and reliability of the solidification operations.

This report was prepared for Ontario Waste Management Corporation by Monenco Limited, who are also responsible for preliminary engineering of the overall Facility. Technical input to this report was provided by Mr. J. R. Conner, who is the specialist consultant on solidification.

1.2 PURPOSE OF THE SOLIDIFICATION PROCESS

At OWMC's proposed Facility, inorganic wastes will be treated by the physical/chemical processes and organic wastes will be destroyed by incineration. The primarily inorganic residues from the above mentioned processes, together with selected residues from waste generators, will be treated by the solidification processes before being disposed of in an engineered landfill.

The objective of the solidification process is to produce a material which is both physically and chemically stable under the environmental conditions expected at the engineered landfill and to minimize the level of contaminants in the leachate. These conditions include the amount of precipitation such as rainfall, which infiltrates into the landfill, and temperature variations including the freeze-thaw cycle.

"Physically stable" means that the solids produced will not revert back to their original liquid or sludge state. The solidified material has good workability characteristics during placement in the landfill and develops good compressive (load bearing) strength characteristics which are expected to be retained indefinitely. "Chemically stable" means that the solidification processes not only chemically solidify the residues, but also render insoluble, immobilize and otherwise react with contaminants in the residues, and thereby minimize the rate at which these contaminants will dissolve in water (leaching) due to the infiltration of water into the landfill.

The solidification processes employ controlled reactions between the reagents and the residues. One of the basic criteria in formulating these systems, is that the chemical reagents used are safe to handle. They are formed from either natural or synthetic materials which have a long history of industrial use.

CHAPTER 2

BASIS FOR TECHNOLOGY SELECTION AND CONCEPTUAL DESIGN

2.1 INTRODUCTION

An important aspect in the evaluation and selection of appropriate solidification technologies for OWMC's treatment Facility is the definition, to the extent possible, of the framework within which the selected solidification processes can be expected to operate. This framework is defined by:

- OWMC's philosophies,
- type and quantities of residues which are likely to require treatment in the solidification plant,
- treatment philosophies and objectives which have been established for the design of the solidification plant, and
- capabilities of the solidification plant in relation to those of the other major plants, notably incineration and physical/chemical treatment, within OWMC's Facility.

The following sections discuss the manner in which these factors have influenced technology selection and system design in the solidification plant.

2.2 OWMC PHILOSOPHY

OWMC has established several basic planning and engineering principles which are central to technology selection and system design in all areas of the proposed treatment Facility including the solidification plant. The following points summarize these key treatment philosophies.

- OWMC's primary responsibility is to establish and operate a liquid industrial waste and hazardous waste management system in Ontario. It has no responsibility for managing municipal solid waste or radioactive waste, nor is it a regulator of other industrial waste management systems.

- OWMC facilities, no matter how large or small they ultimately may be, must be designed to handle all types of special waste. This full service capability is inherent in OWMC's responsibility as a provincial crown agency.

- Wastes must undergo treatment to the fullest extent possible, using best available proven technologies, prior to the safe disposal of the remaining treated residues.

- Up to now, solidification has mostly been applied to untreated wastes such that the leachate generated by regulatory tests on the solidified material is of sufficient quality to allow co-disposal of the solidified materials in municipal landfills.

  At OWMC's Facility, solidification will be applied to residues from treatment of waste, where contaminants have been rendered as insoluble as possible, and the solidified material will subsequently be placed in an engineered landfill, providing an extremely high level of containment.

- It is the Corporation's goal, in order of priority, to:
  - minimize risk to human health,
  - minimize environmental impacts, and
  - minimize financial costs to OWMC and the people of Ontario.

2.3 WASTE PROFILE

OWMC commissioned a waste quantities study in Phase 1 of the Facilities Development Process which proposed a classification of Ontario special waste and estimated the quantities of each (Ref: OWMC[1,3,11], The Proctor & Redfern Group[12]). Additional work has subsequently been conducted to improve available data and the assumptions on the quantities and characteristics of wastes it will be receiving for treatment and disposal. These most recent data have been used as a basis for ensuring that the solidification plant will have the necessary processes, capacity and flexibility to respond to the waste treatment and disposal needs of industries in Ontario.

Table 1 summarizes the waste classes and waste quantities based on the typical waste profile as well as the treatment residues from other process areas which are likely candidates for solidification.

It is recognized that waste type and quantities expected at OWMC's Facility can change over time. Appropriate assumptions have been included in the design of the solidification plant to take this into account and are summarized in Section 2.5 (p. 10).

TABLE 1
CANDIDATE TREATMENT RESIDUES FOR SOLIDIFICATION

OWMC CLASS	DESCRIPTION	TYPICAL TOTAL QUANTITY(5) EXPECTED AT OWMC FACILITY (t/a)	TYPICAL WASTE QUANTITIES TO: ORGANIC INCINERATION (t/a)	TYPICAL WASTE QUANTITIES TO: INORGANIC PHYS/CHEM (t/a)	INORGANIC RESIDUES TO: SOLIDIFICATION (t/a)
1	Organic Waste Sludges and Still Bottoms	11 050	9 580	1 470	0
2	Solvents and Organic Solutions	3 330	3 330	0	0
3	Oil and Grease	880	880	0	0
4	Oil and Water Mixtures	3 530	3 530	0	0
5	Organic and Oily Residues	6 030	3 790	2 240	0
6	Heavy Metal Solutions and Residuals	79 480	0	66 050	13 430(1)
7	Miscellaneous Chemicals and Products	3 100	860	2 240	0
8	Paint and Organic Residuals	5 030	4 750	280	0
9	Aqueous Solutions and Organics	1 790	600	1 190	0
10	Anion Complexes	1 070	0	1 070	0
11	Sludges and Inorganic Residuals	32 030	0	12 660	19 370(1)
12	Pesticide and Herbicide Waste	180	180	0	0
13	PCB Wastes	30	30	0	0
14	Clean Up Residuals	2 470	2 470	0	0
	SUB-TOTAL TO SOLIDIFICATION (RIGHT COLUMN)	150 000	30 000	87 200 plus	32 800
				= 120 000	
	Solid Residues from Incineration Plant (Salt/Ash)				6 500(2)
	Solid Residues from Physical/Chemical Plant (Filter Cake)				19 000(3)
	Liquid Residues from Physical/Chemical Plant (Evaporator Blowdown)(4)				20 700(3)
	TOTAL TO SOLIDIFICATION				79 000

Notes:

1. In many instances these are residues resulting from treatment of waste at the waste generator's facility.
2. These residues will be solidified by a dedicated solidification system at the incineration plant.
3. These are residues resulting from the treatment of 87 200 t/a of inorganic wastes in the physical/chemical plant.
4. Based on discharge of treated effluent to atmosphere by evaporation.
5. Quantities are derived from OWMC's waste profile (November 1984) and are rounded off to the nearest 10 t/a.

2.4 PREMISES

Premises are information provided by OWMC or by other studies undertaken by the Corporation which form a basis for work presented in this report. OWMC's basic planning and engineering principles presented in Section 2.2. (p. 5) are premises which apply to OWMC's Facility as a whole including the solidification plant. The following additional premises establish basic criteria for technology selection and system design in the solidification plant.

- The solidification plant will be designed to process residues which are inorganic in nature. All organic wastes which are sent to OWMC's Facility for treatment will be destroyed in a rotary kiln incinerator. The small quantity of residues from the physical/chemical plant which are organic in nature will be incinerated. Solid and liquid inorganic treatment residues from the physical/chemical treatment and incineration plants will be processed in the solidification plant prior to being deposited in an engineered landfill.

- The solidification plant will be designed for an initial capacity to process residues from 120 000 t/a of inorganic special wastes and 30 000 t/a of organic special wastes delivered to OWMC's Facility.

- The solidification plant will be initially operated one shift of 8 hours per day, 5 days per week, 50 weeks per year, to process the residues resulting from 50 000 t/a of inorganic special wastes and 20 000 t/a of organic special wastes delivered to the Facility.

- Additional shifts will be operated as required to achieve sufficient solidification capacity to process the anticipated quantities of treatment residues when the Facility is operating at its initial capacity of 150 000 t/a.

- The solidification plant will be capable of expansion to process treatment residues resulting from 240 000 t/a of inorganic wastes and 60 000 t/a of organic wastes delivered to the Facility.

- Space will be provided to enable the solidification plant to be expanded to achieve the ultimate Facility design capacity of 300 000 t/a.

- The arrival of wastes at the Facility will be scheduled in advance.

- The types and quantities of residues which are expected to require treatment in the solidification plant have been defined to the extent possible by OWMC's Waste Profile information.

- The data shown in bold face on Table 1 are typical of the types and quantities of materials the solidification plant could receive. However, variations may result from:

  - effectiveness of OWMC's 4R program, the purpose of which is to encourge industry in Ontario to Reduce, Recover, Recycle and Reuse industrial waste,
  - industry's reponse to market demands and to financial constraints,
  - process and manufacturing changes, and
  - changes in Provincial waste regulations.

  On this basis it is important that the solidification process design incorporate features such as:

  - maximum flexibility,
  - future expansion capability, and
  - reserve storage and treatment capacity.

2.5 POSTULATES

Postulates are overriding assumptions which have been made that are basic to the approach used to evaluate alternatives and arrive at an optimum process design. The key assumptions, treatment objectives and treatment philosophies which have influenced technology evaluations and system design in the solidification plant are summarized below.

- The solidification plant will be designed to achieve the following treatment objectives:

  To treat solid and liquid inorganic treatment residues from the incineration and physical/chemical treatment plants such that the solidified material will:

  - be physically stable such that the solids produced will not revert back to their original liquid or sludge state, i.e. will change only very slowly in the landfill, essentially on the same time scale as natural rocks and minerals, and

  - be chemically stable such that the solidification processes not only chemically solidify the waste, but also render insoluble, immobilize and otherwise react with the contaminants in the residues, and thereby minimize the rate at which these contaminants will dissolve in water (leaching) due to the infiltration of water into the landfill.

  To process selected residues from waste generator's facilities to the same quality objectives as treatment residues, described above.

  To solidify inorganic treated liquid streams from the physical/chemical processes which cannot be discharged from the Facility, for reasons stated in Section 3.6.1 (p. 41) and to the same quality objectives as treatment residues.

To ensure that treatment operations can be carried out safely.

- Solidification will not be applied to hazardous, raw wastes. Such wastes will either be destroyed in the incineration plant or pretreated in the physical/chemical plant to produce residues that can then be treated in the solidification plant.

- Technology selection will be directed toward selecting a preferred combination of solidification technologies which are best suited for the range of residues to be processed, recognizing that no single solidification technology is capable of fulfilling all of the process requirements for all of the treatment residues expected.

- The solidification plant will treat all residues in a batchwise fashion. This mode of operation has been adopted to maximize control and effectiveness of treatment. Hence, technologies must permit individual batches to be treated separately without cross contamination or intermixing.

- In evaluating and comparing alternative solidification technologies, emphasis was placed on four criteria: performance, safety, flexibility, and reliability (all of which address environmental impacts) to ensure that the treatment processes selected represent best available proven technology in keeping with OWMC's objectives.

- Changes and improvements will be made as required throughout the life of the plant to adapt to changing waste profiles and technological improvements and to maintain the efficiency of the system for achieving the best possible treatment.

- Laboratory scale treatability tests will be carried out on samples in advance of solidifying residues in the plant, in order to:

- ensure that the treatment efficiency will not be adversely affected by blending certain residues prior to or during treatment,
- select the optimum solidification formulation,
- determine optimum process conditions, and
- verify the quality of the solidified material.

Solidification technologies which do not lend themselves to laboratory testing or are unable to produce the required results within a reasonable period of time were considered to be less suitable for this application.

- The solidification plant will be designed to process residues in solid or liquid form or in mixtures of solids and liquids ranging from slurries to pastes.

- Based on the broad categories of residues that are candidates for solidification (Section 2.4, Table 1, p. 7), it is evident that there are two predominantly different types of feed to the solidification plant. These are:

  - non-pumpable, high solids content material, and
  - pumpable, low solids content material

  which require different handling and processing methods. Hence, the solidification plant will comprise a high solids content treatment system and a low solids content treatment system.

- The selected design capacity of the solidification system will be capable of accommodating the design flow rate of treated liquid effluent streams from the physical/chemical plant so that these streams can be solidified if, for whatever reason, they are unable to be discharged by evaporation, from the Facility.

CHAPTER 3

TECHNOLOGY EVALUATION AND SELECTION

3.1 INTRODUCTION

The framework within which the selected solidification technologies will be expected to operate has been discussed in the previous chapter. This chapter identifies the methodology and criteria for technology selection, and describes the detailed evaluation and selection of a preferred combination of solidification technologies that will be included in the conceptual design of the solidification plant.

3.2 METHODOLOGY

The following points summarize the methodology used to evaluate alternative technologies for inclusion in the solidification plant.

- Establish the major treatment objectives and key treatment philosophies for the proposed solidification process area.
- Establish criteria for technology selection.
- Prepare a "long list" of possible solidification technologies.
- Establish a "short list" of potentially suitable technologies from the "long list" of technologies, by eliminating technologies that are not proven, or not suitable for OWMC's Facility.

- Define specific process requirements for the solidification plant and list alternative technologies which are potentially capable of meeting these objectives.

- Evaluate and rank the relative suitability of each technology according to established criteria and select one or more preferred technologies for inclusion in the conceptual design.

- Design and optimize the resulting solidification systems to satisfy the treatment objectives and treatment philosophies established for solidification.

3.3 CRITERIA FOR TECHNOLOGY SELECTION

Only proven technologies will be considered for use in the solidification plant and some technologies were eliminated from further consideration based on this "screening" criteria alone. Technologies will be considered "proven" if they have commercially demonstrated to perform reliably for a period of at least 12 months on a scale and in a manner comparable with that required for the OWMC Facility.

Potentially suitable solidification technologies were evaluated against the following technology evaluation criteria:

- Performance
- Safety
- Flexibility
- Reliability
- Operations
- Commercial and economic
- Canadian benefits

Higher weighting factors were given to the first four evaluation criteria (performance, safety, flexibility, and reliability, all of which address environmental impact), in determining preferred solidification technologies best suited to OWMC's proposed treatment Facility. This consistent approach ensured that OWMC's corporate goals (p. 6) for the design of the treatment Facility were being adhered to in the design of the solidification plant.

A more detailed description of the technology evaluation criteria is provided below.

3.3.1 PERFORMANCE

This criterion recognizes and addresses three elements crucial to the establishment and operation of OWMC's treatment facility, namely that the technologies selected:

- are those which are able to most effectively treat the residues received,
- can be operated in a manner which is efficient in the use of energy, utilities and reagents, and
- produce minimum quantities of solidified material in a form which is most amenable to ultimate disposal in the landfill.

This criterion also reflects the extent to which the technologies have been used elsewhere in full scale industrial waste treatment applications.

These objectives underly the sub-criteria into which the broad category of "performance" has been divided for technology evaluation purposes. These sub-criteria will ensure that OWMC's Facility minimizes impact on the environment in the following manner.

Most Effective Treatment

The characteristics of alternative solidification technologies are compared on their relative ability to immobilize residual contaminants of concern in the treated residue, to the lowest practical level for the broadest range of contaminants that may be expected in the feed material to the solidification plant. This will minimize the concentration of contaminants in the leachate.

A relatively high weighting has been given to this sub-criterion (50% of the total) in recognition of OWMC's desire to establish a treatment facility which most effectively deals with Ontario's special waste. This ensures that the selected system will have least effect on human health and minimizes the potential for negative effects on the environment.

Efficiency: Energy, Utilities, Reagents

The relative efficiency of each process with respect to energy usage, utility requirements and reagent consumption is measured by this sub-criterion.

Minimum energy use and utility requirements are desirable, not only to minimize operating costs, but to reduce impact on the existing infrastructure of the surrounding environment, and in particular the host community, to the lowest possible level.

The minimization of reagent use is desirable since their presence adds to the potential for negative environmental impact of the Facility due to the following:

- Reagent transportation to the Facility and potential releases during storage and use at the Facility.

- The contribution which reagents make to the quantity of solidified material requiring landfill disposal, the resulting incremental increase in landfill area requirements and associated environmental impact.

Solidified Material Characteristics

Preference is given to technologies and process systems which produce the lowest quantities of solidified material and/or those that can detoxify and contain residual contaminants removed from the waste for disposal, to the greatest extent. Preference is also given to technologies which produce solidified material:

- that has a range of initial curing or setting times, from a few hours to about 2 days. This will ensure that the solidified material will not harden too quickly to prevent transport to, and workability in, the landfill. Conversely, too long a curing time is undesirable as the solidified material may not have sufficient bearing strength to support equipment in the landfill, resulting in delays to landfill operations,

- which is in the most convenient physical form for handling in the landfill, and

- which is readily rendered both physically and chemically stable by solidification processes, prior to disposal in the landfill.

Selection of technologies and process systems having these characteristics will not only assure that the Facility design can operate in a cost effective manner, but also that the performance achieves OWMC's principle goals of minimizing risk to human health in the handling and treatment of residues at the Facility, and of minimizing potential for negative effects on the environment arising from solidification and disposal of the solidified material.

Extent Used Elsewhere

The extent to which the process system has been used elsewhere in full scale industrial plants, is an extension of the "proven" screen used to develop the short list of potential technologies.

OWMC's definition of "proven" technology, as used in the screen, stipulates that a technology must have been commercially demonstrated to perform reliably for a period of at least 12 months on a scale and in a manner comparable with that required for the OWMC Facility before its consideration at a more detailed level. It is a means of establishing a list of technologies to be considered. This sub-criterion carries the logic behind the "proven screen" one step further. In order to ascertain with any degree of certainty, the impact a technology will have on the environment, it is necessary to draw from as reliable and extensive a data base as possible in predicting the performance of that technology. The more information available, the more certain OWMC can be on the performance and the environmental impact of a technology. Preference is therefore given to those technologies which have an extensive history of satisfactory performance in similar process applications.

3.3.2 SAFETY

Results of evaluation by the "safety" criterion are the most obvious means by which OWMC measures the degree to which a technology achieves its first two corporate goals; to minimize risk to human health and to minimize impact on the environment. The criterion has been divided into two sub-criteria that correspond to these two goals, and have been given equal weighting in the evaluation process.

Occupational Risk

The occupational risk to employees at the Facility is of primary importance to OWMC, largely because the potential for negative consequences is the greatest for humans in closest contact with special waste at the Facility, during its handling, storage and treatment. This sub-criterion reflects OWMC's desire to minimize risk to human health.

It should be noted that, in the solidification plant, such risk is largely mitigated since the feed to the plant comprises residues resulting from treatment of wastes at the incineration or physical/chemical plants respectively, or are residues of treatment at the generator's facility. Reagents are non-hazardous and are commonly used in industry, such as cement, lime, clay and sodium silicate solution. Any residual risk can therefore be assessed on the basis of quantities of reagent that need to be handled by a given technology, i.e. the larger the quantity, the greater the residual risk. The one exception to this, is the use of flyash as a reagent in some of the processes. The major source of flyash is from thermal power stations burning fossil fuels, which can contain unburned organics. Flyash is classified as a hazardous material by some regulatory authorities such as the U.S. Environmental Protection Agency (USEPA).

Solidification processes do not operate at elevated pressures or temperatures and hence there are no risks due to contact with materials that are under pressure or at high temperatures.

Occupational risks may occur during normal plant conditions or during plant upsets. Risks during normal plant conditions addresses the potential for impact on the worker during everyday operation of the Facility. At the solidification plant, risk during normal operation might be experienced by the worker due to noise levels, or due to direct contact with residues and reagents such as fugitive dusts, which can irritate the eye, nose and throat.

The measure of worker risk during upset conditions acknowledges that some degree of risk may be unavoidable when using technologies that are required to effectively solidify treatment residues. Within the solidification plant, worker risks during upset conditions may result from dust inhalation during the removal of blockages in residue and/or reagent conveyor systems. The inclusion of this element in the selection of technologies ensures that this risk is minimized.

While some risks during normal and upset conditions can be avoided by selecting appropriate technologies, many more can be mitigated by design or operational procedures in the optimization of Facility design. Mitigation is dealt with in Chapter 4, System Design and Optimization.

Environmental Risk

Environmental risk during normal and process upset conditions encompasses the potential for risk, not only to the natural physical and biological environment, but risk to the surrounding human population including the host community.

Technologies which provide the lowest potential for negative environmental impact will be ranked higher than other alternatives for this sub-criterion, in a manner which is consistent with OWMC's commitment to minimize risk to human health and the environment.

Environmental risk during normal operations is a measure of the potential threat to human health and the environment of a technology under normal operating conditions. Technologies are compared in terms of their potential for negative environmental effects in the long term, through gradual release of, and/or build-up of, contaminants in the receiving environment.

At OWMC's Facility, the solidified material will be placed in an engineered landfill. Hence, the medium for release of contaminants to the receiving environment is leachate which may find a pathway from the landfill to the receiving environment. Given the design features of the landfill and the hydrogeological setting of the site, the environmental risk associated with each technology will be compared on the basis of:

- the quantity of solidified material to be landfilled which affects landfill area, and

- the rate of curing in the landfill which may affect the containment of contaminants in the solidified mass, until curing is complete.

Environmental risk during upset conditions is primarily a measure of the potential for sudden contaminant release and the risk to the receiving environment of substances that may be released. In the context of solidification, plant upset conditions will not result in sudden contaminant release to the receiving environment. However, technologies that require larger quantities of reagents, potentially contribute to greater transportation risks and impacts.

3.3.3 FLEXIBILITY

One of the premises which guided the Facility design was a requirement that the Facility have maximum flexibility to treat a wide range of wastes. This requirement is based on the knowledge that wastes received at OWMC's Facility will cover a broad spectrum of both physical and chemical forms. The "flexibility" criterion therefore reflects the need to achieve OWMC's objectives of minimizing risk to human health and impact on the environment for a wide range of waste types and characteristics. It also assesses the ability of technologies to easily and safely handle variations in quantities of waste requiring treatment. Such variations will be reflected, although to a lesser extent, in the residues resulting from treatment in the physical/chemical or incineration plants.

The following sub-criteria are used to measure the relative ability of alternative technologies and process systems in dealing with a wide range of residue types and quantities.

Residue Characteristics

This sub-criterion addresses the relative ability of alternative technologies and process systems in adapting to and accommodating variations in feed composition or type of residue. The variations that will inevitably occur in the type and characteristics of feed material to solidification demand that technologies included in the Facility design have capability to maximize the containment of residual contaminant in the solidified mass for a wide range of residue characteristics.

Technologies which are least sensitive to changes in residue characteristics will be ranked highly against this sub-criterion.

Residue Quantities

The relative ability of alternative technologies in adapting to variations in the quantities of residues requiring treatment, is measured by this sub-criterion.

OWMC cannot accurately predict the volumes of particular wastes it may receive, or the variations that may occur over time spans measured in years, which in turn affects the feed rate of treatment residues to the solidification plant. It is desirable, therefore, that technologies be capable of effectively processing residues over a range of feed rates.

This sub-criterion reflects in part, the relative ability of alternate technologies to be incorporated into solidification systems that can operate satisfactorily at capacities that vary significantly from their design capacity. This flexibility is further explained in Chapter 4, System Design and Optimization.

Rapid Startup/Shutdown

This sub-criterion recognizes that operational flexibility in achieving rapid startup and shutdown of process systems offers distinct advantages in achieving optimum utilization of treatment systems, particularly as they are operated in a batch treatment mode and/or for a limited number of hours/week. Rapid shutdown capability is also important when responding to process upsets requiring immediate response actions.

3.3.4 RELIABILITY

The "reliability" criterion measures the ability of a technology to achieve anticipated results on a consistent basis. This criterion focuses on the physical components of potential technologies and alternative process systems, the extent of their maintenance requirements, the need for spare parts, the availability of reagents and spare parts, the general robustness of the design and its vulnerability to breakdown.

All of these factors influence the reliability of a process system and the ability of the treatment Facility to achieve all three of OWMC's corporate goals. They are reflected in the following five sub-criteria, many of which are to some extent interrelated.

Maintenance Requirements

This sub-criterion reflects a preference for technologies and process systems which minimize the amount and frequency of downtime required for maintenance. The solidification technologies evaluated do not require the use of process systems involving complex maintenance procedures.

Spare Parts

Preference is given to technologies requiring the least number and lowest cost of spare parts inventory.

Availability of Spare Parts and Reagents

This sub-criterion reflects a reluctance to utilize technologies for which spare parts and/or reagents are not readily available. Delays in obtaining either parts or reagents could result in a component of OWMC's Facility being out of operation for an extended period, and this would adversely impact on OWMC's ability to achieve its corporate goals.

Wide variations in the quality of reagents could result in variable quality of solidified material and is therefore undesirable.

Robustness of Equipment

This sub-criterion ranks technologies by the susceptibility of their components to breakdown. Efficient processing of special wastes is dependent on the ability of the equipment to withstand the rigours of extended operation, exposure to a variety of special wastes and variations in process conditions without breaking down or requiring frequent maintenance. It also minimizes costs. This sub-criterion is therefore linked to all three of OWMC's goals.

Vulnerability To Process Upset/Breakdown

The rationale for this sub-criterion is similar to the preceding one, but focuses on the process itself as opposed to the items of equipment of which it is composed. In general, the more complex the technology and the more component parts that the process system has, the more vulnerable it is likely to be to process upset and/or breakdown.

3.3.5 OPERATIONS

The inclusion of this criterion is intended to reflect OWMC's desire to have a Facility which not only has the capability of treating special wastes to the highest practical standards, but also one which is highly operable in terms of its complexity and the extent to which it can be automated. The amount and availability of specialist startup assistance and operator training required for alternative technologies, is a further consideration.

This criterion therefore has a direct bearing on OWMC's ability to achieve its corporate goals once the Facility is in operation.

Complexity

From an operational viewpoint, preference is given to those technologies and process systems which have minimum component parts, are easily understood and simple to operate and maintain.

Degree of Automation

Ranking by this sub-criterion reflects the degree of operator involvement required to monitor and control the process, and the extent to which the operator has control over the process operations, particularly the quality of discharges released to the environment.

While not always practical, an automated process is usually desirable since it removes the potential for human error in waste processing. The ability to provide a process with automatic "fail-safe" and emergency shutdown systems is considered preferable to those relying on manual initiation of safety and shutdown procedures.

Startup Assistance

The extent of startup assistance and special operator training required is influenced by the complexity of Facility design and process operations.

While the nature of OWMC's Facility mandates a high level of startup assistance and special operator training by those having prior experience with the individual technologies and with similar treatment systems, preference will be given to those technologies and process systems which do not require an excessive amount of specialist input. The availability of resources to provide startup assistance and assist in operator training is a further consideration, particularly when considering the use of proprietary designs.

3.3.6 COMMERCIAL AND ECONOMIC

This criterion reflects for the most part, one of OWMC's corporate goals; the desire to minimize the cost of the Facility. Although cost is perceived as one of the negative impacts of the Facility on Ontario, this criterion is given a low weight relative to criteria that measure the minimization of impact on human health and the environment. The sub-criteria used to compare the alternative technologies and process systems are further described below.

Restrictions on Use

Preference is given to those technologies where no restrictions exist on their use by OWMC for the present or any future applications.

Cost

A high weighting (70% of the total) has been given to this sub-criterion in recognition of the third of OWMC's corporate goals. The cost factor includes consideration of capital costs, operating costs, license fees and potential for return on investment.

Supplier Competition and Reliability

The extent of supplier competition in the marketplace may have an indirect bearing on the cost to OWMC of including a given technology or process system in the Facility design. The reliability of known equipment or process suppliers may have an influence on the selection of a technology if it can only be obtained from a single source, i.e. the technological advantages may be tempered by concerns regarding the supplier's ability to honour contractual commitments.

Delivery

Although unlikely at this stage of the project, it is possible that the selection of a technology or process system could be influenced by an extraordinarily long delivery period, raising concerns on whether the Facility could be completed on schedule.

3.3.7 CANADIAN BENEFITS

Alternative technologies were examined to determine whether any benefits would be accrued to Canada should one technology be selected over another. This criterion is a measure of the potential positive impacts of the Facility.

The sub-criteria used to compare the alternative technologies and process systems are further described below.

Engineering

Preference is given to technologies which can be engineered in Canada.

Supply

Preference is given to those technologies which can be supplied and/or fabricated in Canada.

Technology Transfer

This sub-criterion reflects OWMC's preference to promote the transfer of knowhow to Canadian engineers and suppliers where such knowhow can only presently be obtained outside of Canada.

Where technologies are unavailable in Canada, preference is given to technologies and/or technology vendors who are able and willing to facilitate the transfer of knowhow to Canada.

3.3.8 APPLICATION OF THE TECHNOLOGY EVALUATION CRITERIA

Each of the evaluation criteria was given a numerical weighting factor which reflects the order of importance of each criterion in the technology assessment process. The weighting factors presented below were reviewed and agreed upon with OWMC. Performance, safety, flexibility and reliability were considered to be criteria of greatest importance in view of OWMC's stated goals to minimize risk to human health, minimize environmental impacts, and minimize financial costs to OWMC and the people of Ontario, and these were therefore given the highest overall weightings. Criteria relating to operations, commercial and economic considerations and

Canadian benefits were assigned lower weighting factors consistent with these goals.

Criteria		Weighting Factor
Performance		20
Safety		20
Flexibility		20
Reliability		15
Operations		10
Commercial and economic		10
Canadian benefits		5
	Total	100

Each of the sub-criteria used to assess the above criteria was also assigned weighting factors to facilitate the evaluation process. These weighting factors are summarized as follows:

Criteria	Sub-Criteria		Weighting Factors
Performance			
	Most effective treatment		10
	Efficiency - energy, utilities, reagents etc.		2
	Solidified material characteristics		2
	Extent used elsewhere		6
		Total	20
Safety			
	Occupational risk		10
	Environmental risk		10
		Total	20
Flexibility			
	Residue characteristics		7
	Residue quantities		7
	Rapid startup/shutdown		6
		Total	20

Criteria	Sub-Criteria	Weighting Factors
Reliability		
	Maintenance requirements	1
	Spare parts	2
	Availability of spare parts and reagents	3
	Robustness of equipment	1
	Vulnerability to process upset/breakdown	8
	Total	15
Operations		
	Complexity	6
	Degree of automation	3
	Startup assistance	1
	Total	10
Commercial and Economic		
	Restrictions on use	1
	Cost	7
	Supplier competition and reliability	1
	Delivery	1
	Total	10
Canadian Benefits		
	Engineering	1
	Supply	2
	Technology transfer	2
	Total	5

Alternative solidification technologies were compared for their relative abilities to fulfill each of the above sub-criteria by rating them on a scale of 1 to 5. Those technologies which were best suited to fulfilling a particular criterion were given the highest rating. Technologies which were considered to be equivalent in their abilities to fulfill a particular criterion were given equal ratings. The ratings given each technology were multiplied by the weighting factors assigned to each criterion to arrive at a total weighted score for each technology against each of the selection criteria. The results are presented in Appendix A.

The summation of the weighted scores for each technology provides a quantitative indication of the relative preference for each solidification technology. The higher the score the more preferable the technology. The total weighted scores for each technology were only used to compare technologies and no particular significance is attached to the absolute values.

It should be noted that this methodology has been adopted to assist in the technology selection process to enable all of the technology selection criteria to be accounted for in a rational manner during the evaluation process and to ensure that emphasis is placed on the most important criteria. This process does not eliminate the need for qualitative evaluation and engineering judgement in the assignment of rating values.

Such qualitative evaluations and judgement are based on experience with similar technologies and are necessary in the absence of equally detailed and quantifiable information on every one of the technologies under consideration, to avoid unnecessarily harsh penalization of any technology solely because information is not readily available.

3.4 LONG LIST OF AVAILABLE TECHNOLOGIES

Several generic solidification technologies have been previously reviewed in the context of the particular requirements of OWMC's treatment Facility (Ref: The Proctor & Redfern Group[2]). J.R. Conner has extended this review to include a total of 68 solidification processes grouped under 19 generic technologies. Together, these two sources have identified all of the possible technologies which are likely to be applicable to the solidification of treatment residues. The "long list" of available generic solidification technologies derived from these reviews has been adopted as a datum for the evaluation and selection of the preferred combination of proven, best available technologies in the conceptual design of the solidification plant. This long list of solidification technologies is as follows:

- Portland Cement Based
- Portland Cement/Lime
- Portland Cement/Clay
- Portland Cement/Soluble Silicate
- Portland Cement/Aluminates
- Soluble Silicate Based
- Portland Cement/Flyash
- Lime/Flyash
- Lime/Clay
- Lime Based
- Cement Kiln Dust
- Lime Kiln Dust
- Flyash/Cement Kiln Dust
- Gypsum Based
- Thermoplastic
- Organic Polymerization
- Glassification
- Gross Encapsulation
- Miscellaneous

The long list excludes specific proprietary technologies except where such technologies embrace the overall generic technology, and specific proprietary products that are available for treatment of wastes at the generating source.

The various processes that are grouped under each generic technology are listed in Appendix D. It should be noted that the term "Miscellaneous" refers to technologies that have been used in specific applications and do not come under any of the other generic technologies.

3.5 SELECTION OF SHORT LIST OF POTENTIALLY SUITABLE TECHNOLOGIES

In order to reduce the long list of available technologies to a short list of potentially suitable technologies the following "screens" were used.

3.5.1 PROVEN TECHNOLOGY "SCREEN"

Many of the technologies in the long list have been proven in full scale solidification plants and are identified on column (2) of Table 2, (p.32). However, some of the technologies listed do not meet the "proven technology" criterion as defined in Section 3.3 (p.14). The following technologies were eliminated from consideration at the present time based on this factor alone:

- Portland Cement/Aluminates
- Soluble Silicate-Based
- Flyash/Cement Kiln Dust
- Gypsum Based
- Gross Encapsulation

A brief description of the generic technologies which have been eliminated from further consideration follows, along with specific reasons why each has been omitted.

Portland Cement/Aluminates

This technology is offered as a modification of the Portland Cement based technology, but to our knowledge, it has not yet been employed in the full scale treatment of special wastes nor is there any supporting reference in the literature. This generic technology is therefore eliminated as it is not proven.

TABLE 2
EVALUATION OF POTENTIALLY SUITABLE SOLIDIFICATION TECHNOLOGIES

Technology (1)	Is Technology Proven? (2)	Suitable for OWMC Facility? (3)	Generic Technology Short-Listed (4)
PORTLAND CEMENT BASED	Yes	Yes	Yes
PORTLAND CEMENT/LIME	Yes	Yes	Yes
PORTLAND CEMENT/CLAY	Yes	Yes	Yes
PORTLAND CEMENT/SOLUBLE SILICATE	Yes	Yes	Yes
PORTLAND CEMENT/ALUMINATES	No	No	No
SOLUBLE SILICATE BASED	No	No	No
PORTLAND CEMENT/FLYASH	Yes	Yes	Yes
LIME/FLYASH	Yes	Yes	Yes
LIME/CLAY	Yes	Yes	Yes
LIME BASED	Yes	No	No
CEMENT KILN DUST	Yes	Yes	Yes
LIME KILN DUST	Yes	Yes	Yes
FLYASH/CEMENT KILN DUST	No	No	No
GYPSUM-BASED	No	No	No
THERMOPLASTIC	Yes	No	No
ORGANIC POLYMERIZATION	Yes	No	No
GLASSIFICATION	Yes	No	No
GROSS ENCAPSULATION	No	No	No
MISCELLANEOUS	Yes	No	No

Soluble Silicate-Based

This technology is different from the Portland Cement/Soluble Silicate process and has been used in the formation of grouts.

It involves the injection of soluble silicate solutions to unstable soil formations (in-situ) for the purpose of improving the structural characteristics of the soil and results in a grout. The gelling action of the soluble silicate binds the soil together. This technology is the forerunner of the Portland cement/soluble silicate technology. It has been eliminated as it is not proven.

Flyash/Cement Kiln Dust

This is essentially a bulking process and is not technically or commercially proven as a solidification technology. No data are available on the technology or on solidified material characteristics. The technology has therefore been eliminated.

Gypsum-Based

This technology consists of adding gypsum (calcium sulphate hemihydrate) and small amounts of an organic polymer to improve water resistance in low level nuclear waste liquids and to form a solid which is like plaster of Paris. This technology has been tested in the laboratory but has not been employed in industrial waste treatment facilities.

This technology has been eliminated as it is not proven.

Gross Encapsulation

The technology consists of drying high solids content sludges by thermal means and binding them into a solid matrix with organic polymers. The solid matrix is then encapsulated by a thick, fused polyethylene jacket.

This technology has been eliminated since it is not proven.

3.5.2 SUITABLE FOR OWMC FACILITY "SCREEN"

Of the technologies that have been retained for further evaluation, several have only been used in very specialized and restricted applications such as in the solidification of low level radioactive wastes or oil sludges. Experience in such limited applications cannot be extended with confidence to the solidification of a wide range of residues as envisaged at OWMC's Facility, as no data are available on the characteristics of solidified material when such technologies are employed.

These technologies are not suitable for use at OWMC's Facility and were therefore eliminated from consideration at the present time, as indicated in column (3) of Table 2, (p. 32) and listed below:

- Lime Based
- Thermoplastic
- Organic Polymerization
- Glassification
- Miscellaneous

Column (4) of Table 2, (p.32) therefore lists those generic technologies which form the short-list for further detailed evaluation.

A brief description of the generic technologies which have been eliminated by this screen follows, along with specific reasons why each has been omitted.

Lime-Based

This process involves the addition of lime as a bulking agent to waste sludges, which causes the sludges to harden. The lime precipitates any soluble heavy metals in the sludge as their insoluble metal hydroxides. The high reserve alkalinity of the lime prevents the leaching of metals under acidic leaching conditions.

The generic process has been eliminated as it is not proven in the solidification of a range of special industrial residues and very little data are available on solidified material characteristics.

Thermoplastic

Thermoplastic stabilization techniques include the use of bitumen, paraffin and polyethylene as stabilizing agents. In processing radioactive waste, the waste is dried, heated and dispersed through a heated plastic matrix. The mixture is then cooled to solidify the mass and it is usually buried in a secondary containment system such as a steel drum. The technology requires some specialized equipment to heat and mix the waste and plastic matrices. The batch-type operations work well on small quantities but process scale-up for a large facility would be difficult. This technology has been eliminated since it is not proven for solidification of a wide range of residues.

Organic Polymerization

Organic polymer techniques were developed as a response to the requirement for solidification of nuclear waste for transportation. The most thoroughly tested organic polymer solidification technique is the urea-formaldehyde (UF) system. The polymer is generally formed in a batch process where the wet or dry wastes are blended with a copolymer in a waste receptacle (steel drum) or in a specially designed mixer. When these two components are thoroughly mixed, a catalyst is added, and mixing is continued until the catalyst is thoroughly dispersed. Mixing is terminated before the polymer has formed and the resin-waste mixture is transferred to a waste container if necessary. The polymerized material does not chemically combine with the waste but forms a spongy mass that traps the solid particles. Any liquid associated with the waste will remain after polymerization. The polymerized mass must be dried before disposal.

Organic polymer processes have been proven effective for isolating and handling small volumes of low level radioactive wastes. Containers are necessary for disposal of the material in landfills. Scale-up for a central waste management facility would be difficult.

This generic technology has been eliminated since it is not proven in the solidification of a wide range of residues.

Glassification

Where a waste material is extremely dangerous or radioactive, it is possible to combine the waste with silica and either fuse the material in glass or to form a synthetic silicate mineral. Glasses or crystalline silicates are leached very slowly by naturally occurring waters, hence glassification waste products are generally considered to be safe materials for disposal without secondary containment.

Glassification processes are only proven with highly radioactive wastes. Scale-up for a large facility would be difficult since experience has been limited to small quantities. This technology has been eliminated since it is not proven in the solidification of a wide range of residues.

Miscellaneous

Soliroc (TM)

This is not a solidification process but rather, a pretreatment process for very acidic liquid waste.

The essential two steps of the pretreatment are:

- the formation of silicic acid by mixing blast furnace slag (rich in calcium silicate) with acidic waste at a pH of around 1.5, wherein the silicic acid reacts with the heavy metal cations, and
- the "polymerization" of the metalsilicates to form a gel at a pH of around 11 - 12.
- The resultant sludge may be dewatered as necessary to obtain a solids content of 40 - 50%.
- This sludge can then be solidified as an optional third step by further addition of slag/lime or by any other generic solidification process.

The process has been eliminated since:

- it is not applicable for a wide range of residues, and
- OWMC's Facility will employ extensive physical/chemical treatment

prior to solidification, thereby achieving the same residue quality for similar wastes.

Calcilox (TM)

This process is not a solidification process, as such, but rather an improved thickening and densification process in which the Calcilox material (ground steel mill slag) is mixed with the waste and the waste then allowed to settle. The supernatant is drawn off, recycled or discharged, while the settled material compacts and hardens. The process was designed to be used with flue gas desulphurization sludges and on coal waste fines and has been used commercially in two or three installations in the United States. This process has been eliminated since it is not proven in the solidification of a wide range of residues.

Fersona

This is a fixation process which reportedly fixes sodium in a complex structure by reaction with ferric ion and sulphuric acid. This process has not been used in full scale commercial operation and hence has been eliminated.

Note: TM = Trademark

3.5.3 SUMMARY

The long list of available technologies has been reduced to the following short list of potentially suitable technologies by eliminating those technologies discussed in the previous sections. Each of the generic technologies in the short list comprise one or more solidification process(es) that can be made available for implementation at OWMC's proposed Facility. The short list of potentially suitable technologies is as follows:

- Portland Cement Based
- Portland Cement/Lime
- Portland Cement/Clay
- Portland Cement/Soluble Silicate
- Portland Cement/Flyash
- Lime/Flyash
- Lime/Clay
- Cement Kiln Dust or Lime Kiln Dust

All of these technologies have been used commercially for solidification of water-based waste liquids, sludges and filtercakes that are inorganic. A large body of technical information on leachability, physical properties and general stability is available for the first six technologies while less information is generally available for the others. The basis of most of this technical information has been the solidification of wastes that have not been pretreated. The data demonstrates that some technologies are effective in attaining treatment objectives and applicable regulatory requirements for a wide range of waste characteristics, while others have been effective for specific wastes. At OWMC's Facility, solidification will be applied to residues resulting from treatment of wastes. Hence, each of the technologies in the short list could be applied in the solidification of specific residues to produce solidified material that meet the treatment objectives.

3.6 EVALUATION OF POTENTIALLY SUITABLE TECHNOLOGIES

Examination of the typical characteristics of the treatment residues that are candidates for solidification indicates that they can be classified into pumpable low solids content materials, and non-pumpable high solids content materials. Not all of the potentially suitable solidification technologies are capable of fulfilling all of the process requirements to meet the treatment objectives for both high and low solids residues. The solidification plant will therefore consist of a high solids treatment system and a low solids treatment system with one or more solidification technologies being applied to each treatment system.

The focus of the technology evaluation procedures has been to:

- define the process requirements for the two solidification treatment systems,
- identify, from the list of potentially suitable technologies, alternative technologies that are capable of fulfilling the process requirements, and
- select, for each treatment system, one (or more) technologies which best satisfy the technology evaluation criteria and sub-criteria as outlined in Section 3.3 (p 14).

The process requirements, descriptions of the potentially suitable technologies and their evaluation are presented in the following Sections (3.6.1 to 3.6.3). The results of the evaluation procedure are presented in Section 3.7 (p. 58).

3.6.1 PROCESS REQUIREMENTS

The waste profile information has a major influence on the manner in which the process requirements are defined for the solidification plant. It is recognized that the characteristics of the treatment residues can change over time, depending on the type of waste received at the Facility. The process requirements for the solidification plant have therefore been developed with this in mind.

The following conclusions have been drawn regarding the process requirements based on the existing typical waste profile information.

Residues for High Solids Treatment

The following residues will be solidified in the high solids treatment system. Typically, the solids content of filter cakes, sludges and pastes are expected to be between 30 - 40% by weight and the solid residues are substantially dry.

- Selected residues from the waste generator's facilities, typically from OWMC classes 6 and 11 (Ref: Table 1, Section 2.4, p. 7) could be in dry solid form and/or in non-pumpable wet form ranging from sludges to pastes.

- Residues from the incineration plant comprising boiler ash and salt/ash from the flue gas treatment system will be substantially dry. These residues will be treated in a dedicated high solids treatment system at the incineration plant. This is described in Section 4.3.3 on page 73.

- Solid residues from the physical/chemical plant, comprising batches of filtercakes, will range from friable to pasty. Typically these residues will contain 30 - 40% by weight solids consisting of inert materials such as sand or clay particles which were present in the untreated wastes along with solids precipitated from the physical/chemical treatment processes. These precipitates will contain varying concentrations of sparingly soluble salts (e.g. calcium sulphate and calcium carbonate) along with precipitated metal hydroxides and metal sulphides. Some batches of filter cake are likely to contain concentrations of immiscible or dissolved organics which have adsorbed onto the solid particles or remain in the cake moisture. These organic containing residues will be disposed of by incineration. Solidification and leaching tests (during treatability tests) will determine the maximum allowable concentrations of trace organics permitted in the residues to be solidified.

The physical and chemical characteristics of the various residues listed above will vary. The design of the solidification plant should provide separate storage and handling facilities for different residues so that they may be solidified using formulations specific to their individual characteristics.

It will also be necessary to provide a capability for blending compatible residues so that solidification formulations and processing time can be optimized.

Residues for Low Solids Treatment

The following liquid treatment residues will be solidified in the low solids treatment system.

- Blowdown from the evaporator, which is used to dispose of treated effluents from the physical/chemical plant. Typically, this stream will contain up to 35% dissolved solids and will be pumpable.

- In addition, capability will be provided to solidify treated liquid streams from the physical/chemical plant for periods when:

  - the polishing treatment step of the physical/chemical plant is shutdown,
  - treated effluent cannot be discharged by evaporation when the evaporator is shutdown or when atmospheric conditions are not conducive to such discharge, or when
  - the internal demand for treated effluent is low (incineration plant is shutdown) and it is necessary to solidify part, or all of the treated effluent.

The above residues will be segregated in terms of receipt, storage and handling prior to solidification using specific formulations, when their characteristics are different.

In addition, the capability to blend compatible residues will be provided so that solidification formulations and processing time can be optimized.

Solidification Technology Requirements

In addition to the treatment objectives stated in the first postulate (Section 2.5, p. 10), the potentially suitable solidification technologies for both the high solids and low solids treatment systems have also been evaluated on the basis of their capability to achieve the following:

- The technology employed should be such that the weight and volume increases due to solidification are kept to a minimum at the desired performance level. This will result in the lowest quantity of solidified material being placed in the landfill, and the lowest quantity of reagents requiring transportation to, and handling at, the Facility.

- The solidification formulations utilized by the processes must be sufficiently flexible to provide a range of initial curing (setting) times, from a few hours to about 2 days. This will ensure that the solidified material will not harden too quickly to prevent transport to, or workability in, the landfill. Conversely, too long a setting time is undesirable as the solidified material may not have sufficient bearing strength to support equipment in the landfill, resulting in delays in the landfill operations.

The above requirements are included in the criteria and sub-criteria for technology evaluation, as discussed under Section 3.3 on page 17 and highlighted in the evaluation of the potentially suitable technologies in Section 3.6.3 (p 47).

All the eight potentially suitable technologies comprising the short list were evaluated for both the high solids treatment system and the low solids treatment system.

3.6.2 DESCRIPTION OF POTENTIALLY SUITABLE TECHNOLOGIES

Each of the eight potentially suitable technologies are described in the following sections.

Portland Cement Based (Including Portland Cement/Lime and Portland Cement/Clay)

Portland cement based technology can be classified into two different types; Portland cement alone and Portland cement plus additives such as lime or clay. The following description is applicable to all of these technologies.

With the Portland cement based technology, water in the residue reacts chemically with the Portland cement to form hydrated silicate and aluminate compounds. Solids in the residue act as an aggregate to form a "concrete", although the types of solids encountered in wet residue may produce a concrete of low strength. The optimum combination of residue and Portland cement, the type of Portland cement chosen, and any additives, will vary with the residue type and its composition. Portland cement requires a minimum amount of water to obtain workability. This minimum water to Portland cement ratio is approximately 1:3 by weight, but will also depend on the residue itself, since some solids in the residue can absorb large amounts of water.

Optimum formulations should consider each residue individually because of possible interactions between the residue constituents and the cement. One such interaction is the effect on setting of the cement matrix. Acceleration of the set can result in the cement hardening in the processing equipment. However, chemicals such as boric acid and borate salts retard the setting of Portland cement and appropriate addition of retarders can be used to control the set time. Other substances in wastes which can be deleterious to the setting (curing) reactions of Portland cement (for up to several days) include organic compounds, silt, coal and lignite, some inorganic salts and metal compounds. Very fine particles such as those present in silt and clay can weaken the bond between the cement paste and the particulates by particle coating action. Salts of manganese, tin, zinc, copper and lead are active in reducing strength, and other salts such as sodium phosphate, sodium iodate, sodium sulfide and sodium borate are potential retarders. In some cases, the addition of the lime to the Portland cement has been found to counteract the retarding action and allow a proper set to be achieved. Sodium silicate has been used for the same purpose. Appendix C provides details of major installations employing this technology (Ref. on Technology: 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24 and 25).

Portland Cement/Flyash

Portland cement and flyash have been used in flyash concrete for many decades (Ref: Laguna[17]). Flyash imparts many desirable properties to concretes for certain usages, the most important of which is significant economy because it replaces 25 to 35% of the Portland cement normally used. Because of such wide usage and the fact that flyash is a residue in itself, cement/flyash mixtures were used as a solidification system in the early days of solidification.

J. R. Conner's experience has shown that for the solidification of relatively low solids wastes, i.e., 5 to 15% solids, additive ratios of one to two parts Portland cement/flyash per part of residue by weight were required to prevent settling and achieve good solidification, using Portland cement/flyash ratios of one part of Portland cement to three or four parts of flyash. In high solids residues, where settling is not a problem, cost savings can be achieved by substituting flyash for part of the Portland cement in the mixture. However, this results in larger volume and weight increases than with Portland cement alone, and thus is only justified where very low handling, transportation and disposal costs exist.

Flyash in a Portland cement/flyash system acts both as a bulking agent and as a pozzolan. While most flyashes will not harden by themselves they will exhibit cementing activity (Ref: Clendenning[26]) in the presence of a sufficiently large amount of Portland cement. This is believed to be caused by the release of calcium hydroxide by the Portland cement as it crystallizes. The calcium hydroxide then reacts with the flyash to form calcium aluminum silicates which harden much as Portland cement does. Some flyashes which contain large amounts of free lime are self hardening. The presence of unburned hydrocarbons in the flyash reduce cementing activity and hence it is important to ensure that the flyash employed in this process has acceptable characteristics.

The Stablex Company has done a great deal of technical work on the Portland cement/flyash process and has been involved in a considerable amount of regulatory testing by the USEPA and regulatory agencies in Canada and the United Kingdom (Ref: Taub[27], Stablex[28]). Appendix C provides details of major installations employing this technology (Ref. on Technology: 13, 17, 18, 21, 26, 27, 28 and 29).

Portland Cement/Soluble Silicate

This technology uses Portland cement and soluble silicates, usually sodium silicate in the liquid (38% solution) form, to solidify a wide range of residues. Because the system is quick gelling, it was designed to be used with low solids, rapid settling waste streams to prevent the formation of free-standing water on the surface. It is also useful in fixing certain toxic metal species in a form less soluble than the hydroxides. To date, this technology has been used to treat at least 750 000 m^3 of industrial and municipal liquid wastes (Ref: Conner[39]).

This technology is based on the reactions between soluble silicates and Portland cement, which react in a controlled manner to produce a solid matrix. The matrix itself, as produced, is actually a pseudo-mineral. This displays properties of high stability, high melting point, and a rigid, friable structure similar to many soils (Ref: Conner[30]).

The use of Portland cement and sodium silicate for solidification is generically, in the public domain. However, specific formulations, waste types, and additive ratios have been subsequently patented, and may be valid in certain usages of the technology (e.g. Chemfix). Appendix C provides details of major installations employing this technology (Ref. on

Technology: 13, 15, 18, 21, 23, 25, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44 and 45).

Lime/Flyash

Lime is a general term used to cover the various chemical and physical forms of quick lime and hydrated lime. Combining lime and flyash with water forms a cementitious material on the flyash surface. The reaction product formed is initially a non-crystalline gel, which then becomes calcium silicate hydrate, a compound found in hydrated Portland cements. One of the problems in lime/flyash processes is that flyash is a by-product of coal-burning power plants and its composition is dependent upon not only the composition of the coal burned, but also on how the plant is operated. For example, unburned organics reduce the cementing action by covering reactive surfaces and preventing contact of the cementitious materials. Smaller particles are more reactive than large particles due to the larger surface area. Some flyashes contain large quantities of calcium oxide and have self-hardening characteristics, so that the addition of water alone will produce a cementing reaction without the addition of lime. Use of this process depends strongly on the particular flyash being used and for processes combining lime and flyash, additions of sulfates are often necessary to produce a reliable solidification mixture.

Appendix C provides details of major installations employing this technology (Ref. on Technology: 13, 18, 21, 22, 23, 25, 26, 28, 31, 32, 33, 38, 39, 43, 44, 46, 48, 49 and 50).

Lime/Clay

The oldest processes which exemplify the reaction between lime and various silicas and silicates are the sand/lime mortars used for many centuries before Portland cement was invented. Sand/lime mortars are slow setting and develop their strength only very gradually, since these cementation reactions are very slow compared with most solidification processes at ambient temperature.

The reaction of lime with clays, which are silicates, causes the slow formation of calcium silicates having bonding properties. There is considerable literature on the transformation of clay minerals by calcium hydroxide reaction (Ref: Diamond et al[47]). Appendix C provides details of an installation employing this technology (Ref. on Technology: 13, 18, 21, 23, 25, 26, 43, 44, 48, 49 and 50).

Cement Kiln Dust or Lime Kiln Dust

Cement kiln dust and lime kiln dust have been used on a number of solidification projects, primarily in remedial action for existing disposal sites or spill cleanup in the United States. It is primarily used as an absorbent or bulking agent, or in the case of lime kiln dust, to also neutralize acidic residues. These dusts vary widely in chemistry from source to source, and their sources are uncertain and variable as to both quality and cost.

Lime kiln dust has fairly good neutralizing properties, depending upon the free lime content from the particular source. Since it is a fine dust, it also acts as a bulking agent or absorbent. Cement kiln dust has less neutralizing capacity, although it is alkaline, but it has some cementing ability in most cases, and acts as a poor substitute for cement. It is also a very fine dust and thus acts as a bulking agent or absorbent.

J. R. Conner has solidified various wastes with both of these materials, and also with combinations of cement with both cement kiln dust and lime kiln dust. In most cases, the large volume increase makes the system unattractive. The weight addition ratio is usually at least 2:1. If cement kiln dust or lime kiln dust is received as a waste material at OWMC's Facility, it can be used as a bulking agent in the treatment of some residues, thereby reducing the quantity of cement required for treatment. Appendix C provides details of major installations employing this technology (Ref. on Technology: 18, 21, 25, 44, 52 and 53).

3.6.3 EVALUATION

The relative suitability of the potentially suitable technologies described in Section 3.6.2 has been evaluated to provide a basis for selection of a preferred combination of solidification technologies for inclusion in the preliminary design of the high solids treatment and low solids treatment systems of the solidification plant. The methodology which has been adopted to assist in this evaluation process and enable all of the technology evaluation criteria to be accounted for in a rational manner has been outlined in Sections 3.2 (p. 13) and 3.3 (p. 14) respectively. The evaluation will focus on aspects which differ between the eight technologies considered.

Appendix A contains a numerical comparative evaluation of all the eight technologies in the short list, using the criteria weighting factors identified in Section 3.3.8 (p. 26). Appendix A also identifies the relative advantages and disadvantages of the eight technologies.

The operating costs for solidification by each of the potentially suitable technologies is compared on a unit cost basis in Appendix B. The differences in capital costs between the eight technologies are small when compared to differences in operating costs, and are for this reason ignored in Appendix B.

3.6.3.1 High Solids Treatment System

Portland Cement Based (Including Portland Cement/Lime and Portland Cement/Clay)

These technologies are most suitable overall, for the solidification of high solids content residues for the following reasons:

- In the solidification of high solid content residues, the quantity of reagents required for these technologies is low and hence weight and volume increases are also low. These characteristics rate highly in terms of minimizing impact on the environment, minimizing landfill area requirements and the quantity of reagents to be transported to the Facility.

- The small quantity of reagents required also minimizes risk to human health by minimizing exposure to dust and noise.

- These technologies have the ability to accommodate a wide variation in the characteristics of residues to be solidified as the cement/additive combinations can be varied to suit the residue characteristics.

- These technologies are particularly suited to the solidification of residue sludges and pastes from waste generators which may need some chemical fixation. For example, a sludge of low pH containing only small quantities of heavy metals can be neutralized by the addition of lime which at the same time will fix the heavy metals as their insoluble hydroxides. The lime will also participate in the solidification reactions of the process.

- The technologies thus provide considerable flexibility in the solidification of residues which is a prerequisite of a centralized waste treatment facility as proposed by OWMC, and ensures that a high level of performance can be achieved over a wide range of wastes, thereby minimizing environmental impacts.

- There is considerable operating experience and data for these technologies (Appendix C).

- Operating costs are the lowest of all the potentially suitable technologies when solidifying high solids content residues, satisfying the third of OWMC's goals.

However, it must be noted that while the Portland cement/lime and Portland cement/clay technologies add to the capability of solidifying specific types of residues, individually, these two technologies have the following disadvantages:

- these two technologies cannot accommodate the wide variations in the characteristics of residues by themselves, and o these two technologies require slightly larger reagent quantities and hence result in larger weight and volume increases when compared with the technology using Portland cement plus minor additives.

Portland Cement/Flyash

This technology has the following disadvantages in the solidification of high solids content residues:

o Reagent addition for solidification is of the order of 3 times that of the Portland cement based technology, resulting in large weight and volume increases. This increase in landfill use and transport of reagents results in increased environmental impact.

o The potential for exposure to dust and noise resulting in risk to human health is increased due to higher reagent quantities.

o A large quantity of flyash would be required and the flyash composition can vary from batch to batch. The flyash can also contain unburned hydrocarbons that inhibit solidification.

o Operating costs will be higher in terms of reagent cost (15%) and landfill cost (30%) when compared with the Portland cement based technology.

o Possible variability in flyash composition from one batch to another exists. Also it is judged that this process, at least generically, does not afford the same flexibility of the cement based processes in the solidification of a wide variety of residues that is of prime consideration in a centralized waste treatment facility as proposed by OWMC.

However, it is possible that flyash may be delivered to OWMC's Facility as a residue, for appropriate disposal. In this context, it is noted that some flyashes are designated as hazardous by the US Environmental Protection Agency. To cater to this possibility and in instances where Portland cement/flyash can be used to solidify specific residues if flyash is available at no cost, the conceptual design of the high solids treatment system will have the capability to utilize Portland cement/flyash with the same processing equipment. This limited capability can be easily increased at minimal extra costs if large quantities of flyash become available as a residue and must be processed.

Portland Cement/Soluble Silicate

This technology has the following disadvantages in the solidification of high solids content residues:

- Although the reagent quantity requirements are the same as that for Portland cement based processes, reagent costs will be about 35% higher as soluble silicate is more expensive.

However, since the low solids treatment system will utilize Portland cement/soluble silicate, (see section 3.6.3.2) the capability of soluble silicate addition in the high solids treatment system will be provided so that batches of residues can be solidified using this technology, if appropriate. For example, the soluble silicate can act as a catalyst in the solidification of certain residues and process flexibility will be enhanced in providing this capability.

Lime/Flyash and Lime/Clay

Following are the main disadvantages of these technologies for high solids treatment:

- Technologies are not effective in solidifying a wide range of residues, thereby resulting in lower performance and higher environmental impact than for other options.

- The potential for exposure to dust and noise resulting in risk to human health is increased due to higher reagent quantities.

- Reagent addition is about 5 times that of the Portland cement based processes, resulting in large weight and volume increases. This increases landfill use and transport of reagents, with associated environmental impacts.

- Reactions are slow and curing times are high.

- Plant operation and control require more attention.

- High operating cost both in terms of reagent consumption (especially lime/clay which is about 3 times the cost of Portland cement based technology) and landfill cost (2 times that needed for the Portland cement based technology).

These two technologies do not have any advantages over the other technologies.

Cement Kiln Dust and Lime Kiln Dust

Following are the main disadvantages of these technologies for high solids treatment:

- Technologies are not effective in solidifying a wide range of residues, thereby resulting in lower performance and higher environmental impacts than for other options.

- The potential for exposure to dust and noise resulting in risk to human health is increased due to higher reagent quantities.

- These reagents act as a bulking agent. Hence, reagent addition is up to 5 times that for the Portland cement based technology. This increases landfill use and transport of reagents, with associated environmental impacts.

- Curing times are high.

- Composition of reagents can vary quite considerable from source to source.

- Operating costs are high.

The only situation when these technologies will need to be used at OWMC's Facility is if cement kiln dust and/or lime kiln dust is delivered to the Facility as a designated waste residue and must be processed. Such a situation is considered unlikely as these materials have a long history of use in other industrial sectors, and are not listed as hazardous wastes by the Ministry of the Environment (MOE) in Ontario.

3.6.3.2 Low Solids Treatment System

Portland Cement/Soluble Silicate

This technology is the most suitable overall, for the solidification of treatment residues with low solids content, for the following reasons:

- The presence of the soluble silicate ensures the rapid formation of a gel which holds the water and prevents the settling of solids. Hence, there is no formation of free standing water on the surface of the solidified material, and a high level of performance is achieved.

- The quantity of reagents added to accomplish solidification of low solids content residues is the lowest of all technologies. Hence, weight and volume increases due to solidification are the lowest. This minimizes landfill use and transport of reagents, thereby minimizing associated environmental impacts.

- The small quantity of reagents required also minimizes risk to human health by minimizing exposure to dust and noise.

- Curing time can be varied over the range dictated by operational requirements of the landfill.

- Plant operation and control is simple and requires minimal operator attention.

- The process is the most economical in reagent costs and landfill costs (Appendix B).

- Over 750 000 m^3 of wastes have been solidified using this technology with more than 75% of the wastes comprising low solids content (Appendix C).

However, in rare and specific instances, where residues contain high concentrations of an inhibiting chemical species, such as soluble nitrates, this technology is not effective. In such instances, the residue may be solidified using one of the other Portland cement based technologies or by blending the batch of residue with other compatible residues such that the concentration of the inhibiting species is reduced to a level whereby it does not affect the performance of this technology.

Portland Cement Based (Including Portland Cement/Lime and Portland Cement/Clay)

The following are the main disadvantages of these technologies for the solidification of low solids materials:

- The presence of high water content requires 2 to 3 times the quantity of reagents for solidification by these technologies when compared with the Portland cement/soluble silicate technology. Hence the weight and volume increases due to solidification are high. This increases landfill use and transport of reagents, with associated impact on the environment.

- The potential for exposure to dust and noise resulting in risk to human health is increased due to higher reagent quantities.

- Solidification operations require more attention to prevent free standing water on the surface of solidified material with potential for deterioration in performance.

- Curing times can be long and in instances, greater than 2 days.

- Reagent costs are more than twice that for the Portland cement/soluble silicate technology and landfill costs are more than 1.5 times on the same comparative basis.

However, as stated in the previous section, these technologies are more effective for certain specific residues than the Portland cement/soluble silicate technology.

Portland Cement/Flyash

Following are the main disadvantages of this technology for the solidification of low solids materials:

- Flyash acts as a bulking agent to counteract the large water content when solidifying low solids content residues. Hence, the reagent addition for solidification is of the order of 6 times that of the Portland cement/soluble silicate technology, resulting in large weight and volume increases. This increases landfill use and transport of reagents with significant increase in environmental impact.

- The potential for exposure to dust and noise resulting in risk to human health is increased due to higher reagent quantities.

- A large quantity of flyash would be required and the flyash composition can vary from batch to batch. The flyash can also contain unburned hydrocarbons that inhibit solidification, thereby potentially reducing performance.

- Operating costs will be higher in terms of reagent cost (2 times) and landfill cost (greater than 2 times) when compared with the Portland cement/soluble silicate process.

However, this technology is also more effective in the solidification of some specific residues containing large concentrations of inhibitors, when compared to the Portland cement/soluble silicate technology.

Lime/Flyash and Lime/Clay

Following are the main disadvantages of these technologies for the solidification of low solids materials:

- Technologies are not effective in solidifying a wide range of residues, thereby reducing the ranking of these technologies on performance.
- Reagent addition is about 9 times that of the Portland cement/soluble silicate technology resulting in large weight and volume increases. This increases landfill use and transport of reagents with significant increase in environmental impact.
- The potential for exposure to dust and noise resulting in risk to human health is increased due to higher reagent quantities.
- Reactions are slow and curing times are high.
- Plant operation and control require more attention.
- High operating cost both in terms of reagent consumption (especially lime/clay which is 6 times the cost of Portland cement/soluble silicate technology) and landfill cost (3 times that needed for the Portland cement/soluble silicate technology).

These two technologies do not have any advantages over the other technologies.

Cement Kiln Dust or Lime Kiln Dust

Following are the main disadvantages of these technologies for the solidification of low solids materials:

- Technologies are not effective in solidifying a wide range of residues, therby reducing the ranking of these technologies on performance.
- These reagents act as a bulking agent to counteract the high water content in the low solids content residues. Hence, reagent addition is up to 8 times that for the Portland cement/soluble silicate technology, resulting in large weight and volume increases. This increases landfill use and transport of reagents with consequential environmental impact.
- The potential for exposure to dust and noise resulting in risk to human health is increased due to higher reagent quantities.
- Curing times are high.
- Composition of reagents can vary quite considerably from source to source.
- Operating costs are high.

These technologies will need to be used at OWMC's Facility only if cement kiln dust and/or lime kiln dust is delivered to the Facility as a designated waste residue, for disposal. Such a situation is considered unlikely due to reasons stated in section 3.6.3.1 when discussing this technology.

3.7 SELECTION OF PREFERRED TECHNOLOGIES

It should be recognized that this evaluation has been conducted on a project specific basis, and the conclusions may not necessarily apply to other project situations. Previous sections of this chapter described the eight solidification technologies which have been examined as candidates for OWMC's Facility (Section 3.6.2, p. 43) and evaluated them on a comparative basis (Section 3.6.3, p. 47). This section summarizes the rationale for selection of preferred technologies.

3.7.1 PREFERRED TECHNOLOGY FOR HIGH SOLIDS TREATMENT

It can be seen from the evaluation of technologies (described in Section 3.6.3, p. 47, and quantified in Appendix A) that the Portland cement based technology, with minor additives, is preferred for the solidification of high solids content residues. Of all the technologies evaluated, this technology ranks the highest in meeting OWMC's goals and is, overall, best suited for the solidification plant at the OWMC Facility.

However, none of the technologies evaluated can individually be the best applicable, in the solidification of all residues representing a wide range of characteristics. As stated in Section 3.6.3.1 (p. 48), Portland cement/lime, Portland cement/clay, Portland cement/flyash and Portland cement/soluble silicate are potentially more suitable for some specific residues.

Therefore, Portland cement based technologies, with minor additives, has been selected as the preferred technology and will be utilized for the majority of residues that are candidates for high solids treatment. Additionally, the capability to utilize the other technologies stated in the previous paragraph for the solidification of some specific residues will be provided in the design of the solidification plant. This capability is achieved by simply providing storage capacity for the other reagents such as lime, clay and flyash. Soluble silicate will be available for use in this system as it is a reagent for the low solids treatment system (see Section 3.7.2). The main processing equipment of the high solids system is the same when utilizing any of these technologies.

Cement kiln dust and lime kiln dust technologies will be utilized in the solidification plant only in the event that cement kiln dust and/or lime kiln dust are delivered to the Facility as a residue for disposal. These will then be blended with other residues and processed in the high solids system. No additional process equipment would be required.

3.7.2 LOW SOLIDS TREATMENT

The Portland cement/soluble silicate technology is preferred over other technologies for the solidification of pumpable residues in the low solids treatment system and has therefore been selected, based on the evaluation described in Section 3.6.3 (p. 47).

In the event that some pumpable residues contain high concentrations of an inhibiting chemical species such as soluble nitrates, as stated under Section 3.6.3.2 on page 54, these residues can be blended with other compatible residues such that the concentration of the inhibiting species is reduced to a level whereby it does not affect this technology. Alternatively, the residue can be routed to the high solids treatment system and solidified using one of the technologies available in that system, should this permit optimum treatment of the residue.

3.8 SUMMARY

The Portland cement based processes have been selected for the solidification of high solids content residues. It can be seen from the ranking in Appendix A that there is little variance in the points scored by the Portland cement based technology with minor additives and the less preferred technologies such as Portland cement/flyash, Portland cement/soluble silicate, Portland cement/lime and Portland cement/clay. The design of the solidification plant incorporates flexibility by the provision of storage capacity for reagents employed by these less preferred technologies, so that specific residues can be treated by optimum formulations using one of these technologies.

The Portland cement/soluble silicate process has been selected for the solidification of low solids content liquid residues.

The selected technologies for the high solids treatment system and the low solids treatment system consume the lowest quantity of reagents for the solidification of the various residues, compared with other technologies considered, and therefore:

- minimize occupational risk to plant operating personnel by limiting their exposure to dust and noise (these are influenced by the quantity of reagents handled),
- minimize environmental risk by:
  - minimizing truck traffic for the transporation of reagents to the Facility
  - minimizing the quantity of solidified material to be deposited in the landfill and hence limiting land use, and,
- minimize financial costs in terms of limiting the quantity of reagents and landfill volume used.

These characteristics demonstrate how OWMC's goals have been influential in selecting solidification technologies for OWMC's Facility.

The selected technologies will also provide the most effective treatment by immobilizing residual contaminants of concern in the treated residues to the best practical level for the broadest range of contaminants that may be expected in the feed material to the solidification plant. Ample data is available to demonstrate the usefulness of solidification technologies in containing contaminants within the solidified mass, and thereby reducing the concentration of contaminants in the leachate. This is further addressed in Chapter 4 where performance of the solidification plant is discussed.

Technical information and data that are available in the public domain for the selected processes are sufficient for the design of the solidification plant.

CHAPTER 4
SYSTEM DESIGN AND OPTIMIZATION

4.1 INTRODUCTION

Previous sections of this report have described the rationale for selecting the preferred combination of proven technologies for inclusion in the design of the solidification plant.

Chapter 4 describes the manner in which these technologies will be assembled into process systems and the steps taken to optimize the design and operation of these systems to ensure that OWMC's goals of minimizing risk to human health, impact on the environment and cost are achieved in a satisfactory manner.

4.2 TREATMENT RESIDUES TO BE SOLIDIFIED

Typical residues that are expected to require solidification are presented in summary form in Table 1 of Section 2.3 (p. 7). Table 3 presents the data from Table 1 in a manner which identifies residues that will be solidified in the high solids content treatment system and those that will be solidified in the low solids content treatment system. The inorganic residues have also been regrouped into dry solids, wet non-pumpable sludges/pastes, and pumpable liquids, based on information from OWMC's waste data, and a review of the characteristics of residues resulting from treatment at the Facility. The physical characteristics of the dry solid and wet non-pumpable sludges/pastes dictate that these residues are

TABLE 3

TREATMENT RESIDUES REQUIRING SOLIDIFICATION

Residue	Tonnes per Annum (t/a)	
High Solids Treatment		
Dry Solid Residues from Generators	16 100	
Wet Non-Pumpable Residues from Generators	16 700	
High Solids Residues from Physical/Chemical Plant (Filter cake)	19 000	
Sub Total		51 800
Dedicated System at Incineration Plant		
Dry Solid Residues from Incineration Plant (salt and ash)		6 500
Low Solids Treatment(1)		
Liquid Residues from Physical/Chemical Plant (Evaporator Blowdown)	20 700	
Flushing Water	900	
Sub Total		21 600
Total		79 900

Note 1: The low solids treatment system design basis will, in addition to the above, provide the capacity to solidify treated liquids from the physical/chemical plant, at a rate of upto 50 t/h, when such liquids cannot be disposed of by evaporation. This matches the design rate of the miscellaneous treatment system in the physical/chemical treatment plant.

solidified in the high solids treatment system, while the pumpable liquids will be solidifed in the low solids treatment system. This establishes the design basis for the solidification plant.

4.3 DESCRIPTION OF SOLIDIFICATION PLANT

Figure 1 is a pictorial flow diagram of the proposed solidification plant which includes the major components of the high solids treatment system and the low solids treatment system. Figure 2 identifies the location of the solidification plant on the Facility, and Figures 3, 4 and 5 show the configuration of equipment in the plant. The following description of the solidification plant should be read in conjunction with these Figures.

4.3.1 FEED STORAGE AND HANDLING

Dry inorganic bulk solid residues from generators will be received and stored in a concrete pit. The pit will be divided into compartments to provide segregation of dry residue batches depending on their characteristics. An overhead crane grab, capable of travelling the length and width of the pit, will transfer the residues in batches to screening and size reduction equipment. Oversize lumps (greater than 25 mm) will be crushed to less than 25 mm and along with the undersize from the screens, will be elevated and conveyed to two mixers of the high solids treatment system, for solidification.

Wet non-pumpable residues from generators will be received and stored in live-bottom bins. Any gross solids will be screened out at the top of the bin and fed to the size reduction equipment described above. The residue batches will be fed by the live bottom bin screws to a skip hoist which will elevate the residue to a conveyor for transport to two other mixers of the high solids treatment system.

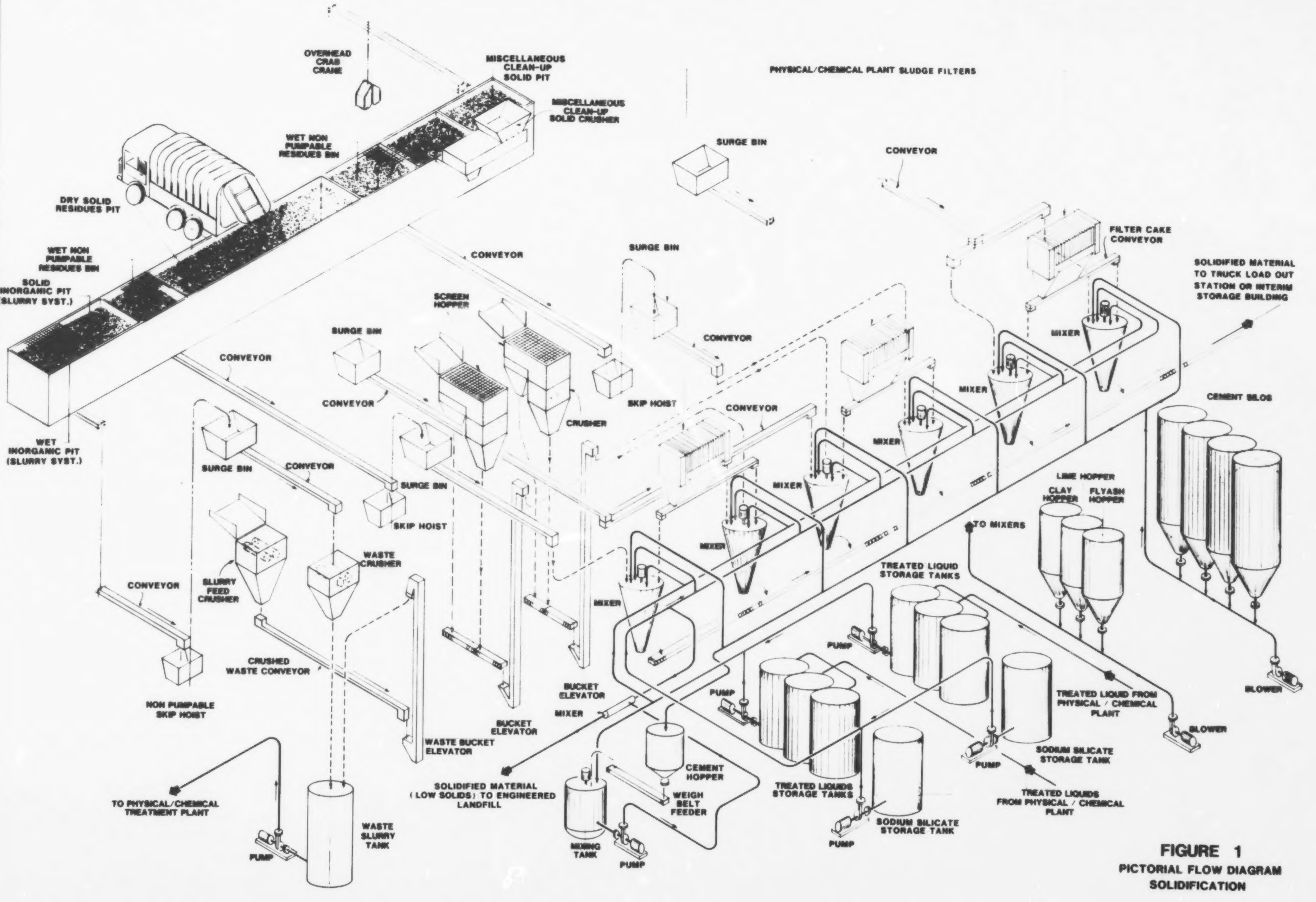

OVERHEAD CRAB CRANE
MISCELLANEOUS CLEAN-UP SOLID PIT
MISCELLANEOUS CLEAN-UP SOLID CRUSHER
PHYSICAL/CHEMICAL PLANT SLUDGE FILTERS
WET NON PUMPABLE RESIDUES BIN
SURGE BIN
CONVEYOR
DRY SOLID RESIDUES PIT
FILTER CAKE CONVEYOR
WET NON PUMPABLE RESIDUES BIN
CONVEYOR
SURGE BIN
SOLID INORGANIC PIT (SLURRY SYST.)
SCREEN HOPPER
SOLIDIFIED MATERIAL TO TRUCK LOAD OUT STATION OR INTERIM STORAGE BUILDING
SURGE BIN
CONVEYOR
MIXER
CONVEYOR
CONVEYOR
SKIP HOIST
MIXER
CEMENT SILOS
CRUSHER
CONVEYOR
WET INORGANIC PIT (SLURRY SYST.)
MIXER
SURGE BIN
CONVEYOR
LIME HOPPER
MIXER
SURGE BIN
CLAY HOPPER
FLYASH HOPPER
SKIP HOIST
MIXER
TO MIXERS
WASTE CRUSHER
TREATED LIQUID STORAGE TANKS
CONVEYOR
SLURRY FEED CRUSHER
MIXER
PUMP
CRUSHED WASTE CONVEYOR
BUCKET ELEVATOR
PUMP
TREATED LIQUID FROM PHYSICAL / CHEMICAL PLANT
BLOWER
NON PUMPABLE SKIP HOIST
MIXER
BUCKET ELEVATOR
BLOWER
WASTE BUCKET ELEVATOR
CEMENT HOPPER
SODIUM SILICATE STORAGE TANK
SOLIDIFIED MATERIAL (LOW SOLIDS) TO ENGINEERED LANDFILL
PUMP
TO PHYSICAL/CHEMICAL TREATMENT PLANT
WEIGH BELT FEEDER
TREATED LIQUIDS STORAGE TANKS
TREATED LIQUIDS FROM PHYSICAL / CHEMICAL PLANT
WASTE SLURRY TANK
SODIUM SILICATE STORAGE TANK
PUMP
MIXING TANK
PUMP
PUMP

FIGURE 1
PICTORIAL FLOW DIAGRAM
SOLIDIFICATION

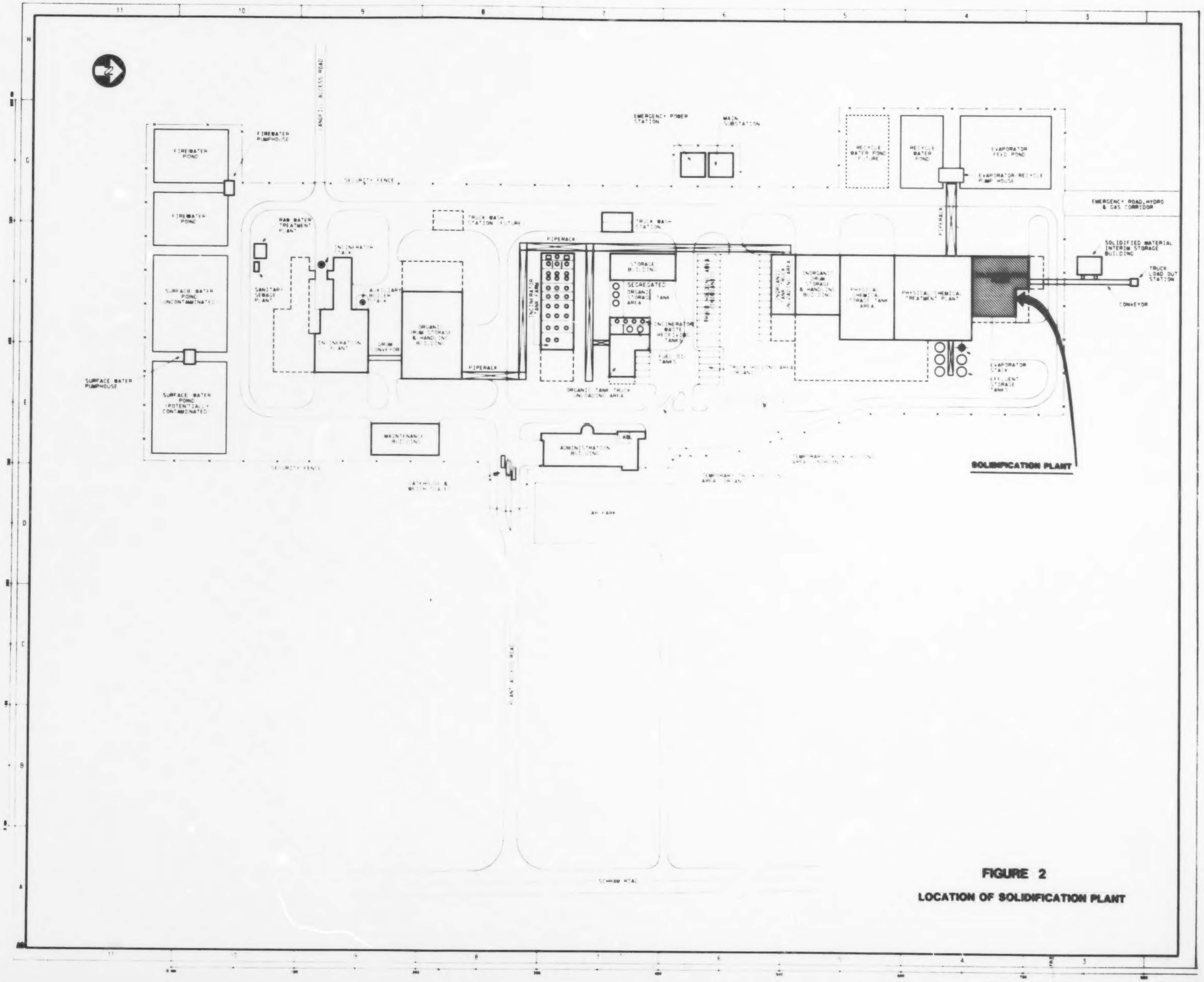

LANDFILL ACCESS ROAD
FIREWATER PUMPHOUSE
FIREWATER POND
FIREWATER POND
SURFACE WATER POND (UNCONTAMINATED)
SURFACE WATER PUMPHOUSE
SURFACE WATER POND (POTENTIALLY CONTAMINATED)
SECURITY FENCE
RAW WATER TREATMENT PLANT
SANITARY SEWAGE PLANT
INCINERATOR STACK
AUXILIARY BOILER STACK
INCINERATION PLANT
DRUM CONVEYOR
TRUCK WASH STATION (FUTURE)
ORGANIC DRUM STORAGE & HANDLING BUILDING
PIPERACK
INCINERATOR TANK FARM
ORGANIC TANK TRUCK UNLOADING AREA
TRUCK WASH STATION
STORAGE BUILDING
SEGREGATED ORGANIC STORAGE TANK AREA
INCINERATOR WASTE RECEIVING TANKS
FUEL OIL TANKS
TRUCK HOLDING AREA ORGANIC
EMERGENCY POWER STATION
MAIN SUBSTATION
RECYCLE WATER POND (FUTURE)
RECYCLE WATER POND
EVAPORATOR FEED POND
EVAPORATOR/RECYCLE PUMP HOUSE
PIPERACK
EMERGENCY ROAD, HYDRO & GAS CORRIDOR
INORGANIC TANK TRUCK UNLOADING AREA
INORGANIC DRUM STORAGE & HANDLING BUILDING
PHYSICAL CHEMICAL STORAGE TANK AREA
PHYSICAL/CHEMICAL TREATMENT PLANT
SOLIDIFIED MATERIAL INTERIM STORAGE BUILDING
TRUCK LOAD OUT STATION
CONVEYOR
EVAPORATOR STACK
EFFLUENT STORAGE TANKS
SOLIDIFICATION PLANT
MAINTENANCE BUILDING
ADMINISTRATION BUILDING
LAB.
GATEHOUSE & WEIGH SCALE
TEMPORARY TRUCK HOLDING AREA INORGANIC
TEMPORARY TRUCK HOLDING AREA ORGANIC
AR FARM
PLANT ACCESS ROAD
SCHRAM ROAD

FIGURE 2

LOCATION OF SOLIDIFICATION PLANT

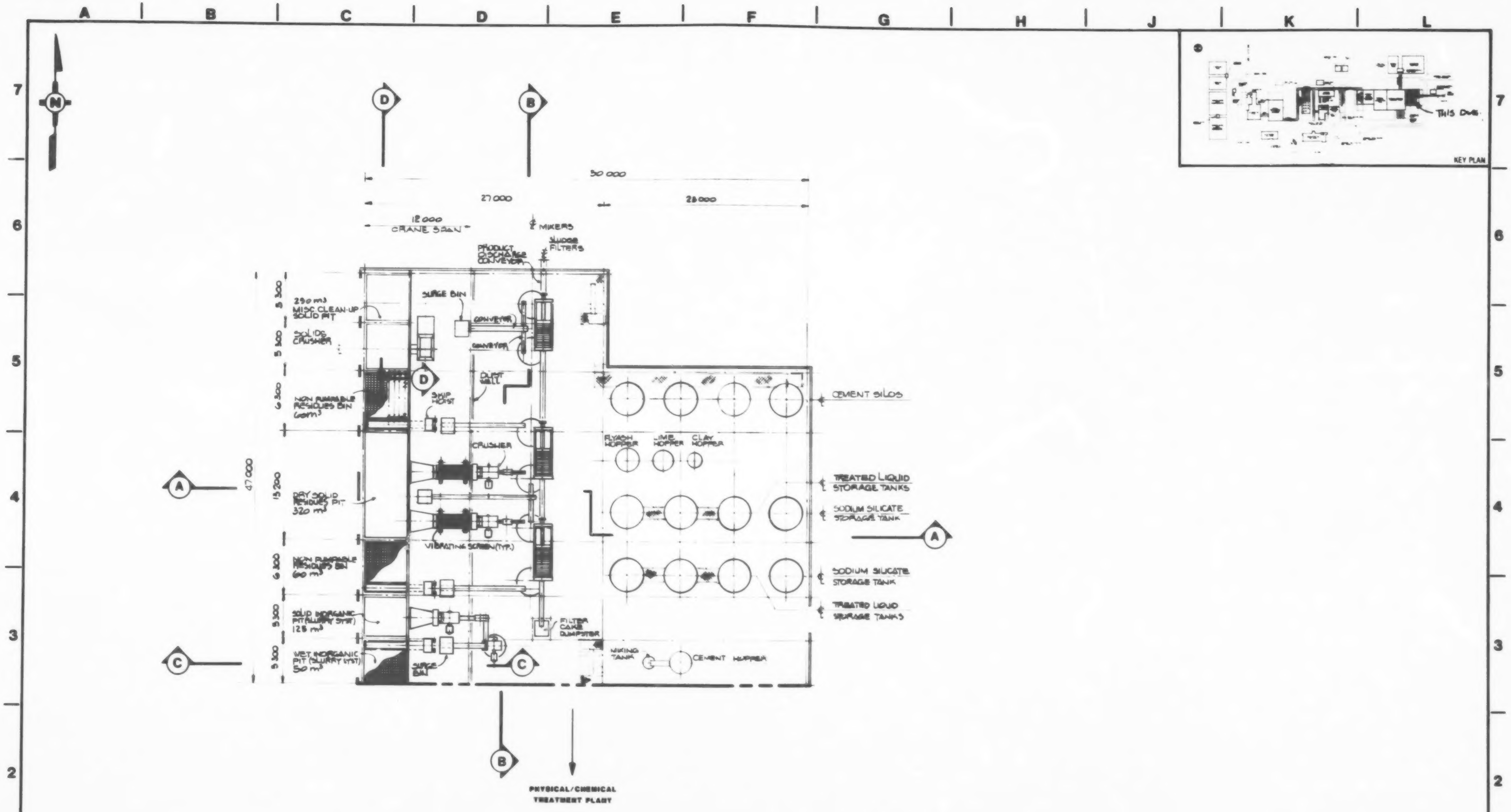
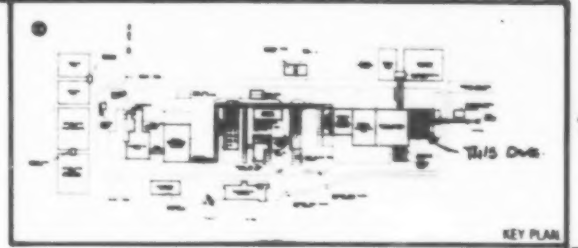

A
B
C
D
E
F
G
H
J
K
L
7
6
5
4
3
2
1
N
D
B
30 000
27 000
23 000
12 000
CRANE SPAN
℄ MIXERS
SLUDGE FILTERS
PRODUCT DISCHARGE CONVEYOR
5 300
5 300
6 300
15 200
6 300
5 300
5 300
47 000
290 m3 MISC. CLEAN-UP SOLID PIT
SOLIDS CRUSHER
SURGE BIN
CONVEYOR
CONVEYOR
DUST WALL
NON PUMPABLE RESIDUES BIN 60 m³
SKIP HOIST
CRUSHER
DRY SOLID RESIDUES PIT 320 m³
VIBRATING SCREEN (TYP.)
NON PUMPABLE RESIDUES BIN 60 m³
SOLID INORGANIC PIT (SLURRY SYST.) 125 m³
WET INORGANIC PIT (SLURRY SYST.) 50 m³
SURGE BIN
FILTER CAKE DUMPSTER
MIXING TANK
CEMENT HOPPER
CEMENT SILOS
FLYASH HOPPER
LIME HOPPER
CLAY HOPPER
℄ TREATED LIQUID STORAGE TANKS
℄ SODIUM SILICATE STORAGE TANK
℄ SODIUM SILICATE STORAGE TANK
℄ TREATED LIQUID STORAGE TANKS
A
A
C
C
B
PHYSICAL/CHEMICAL TREATMENT PLANT
THIS DWG.
KEY PLAN

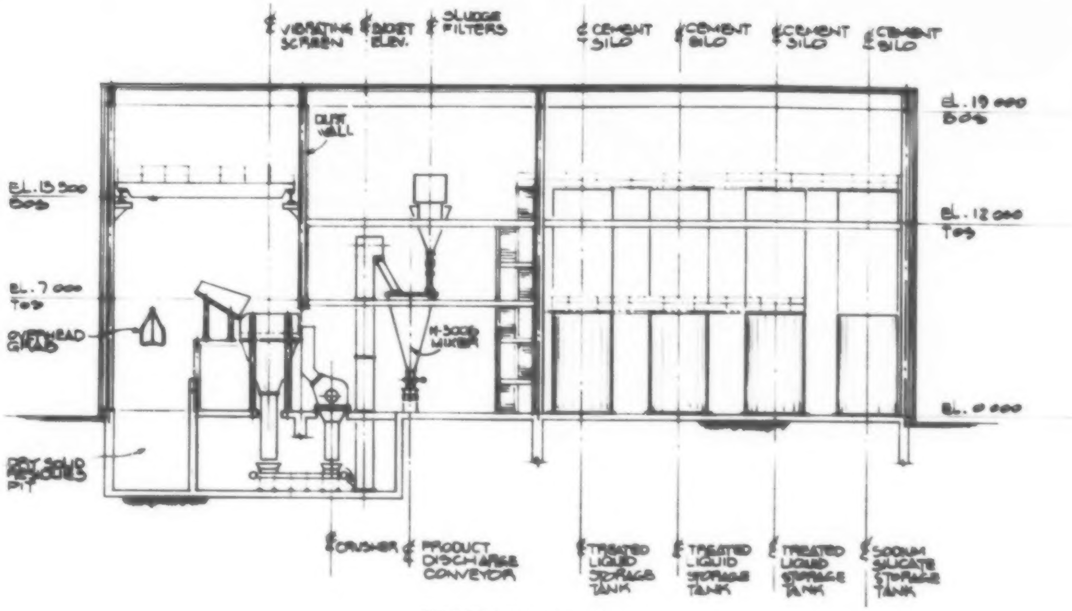
FIGURE 3

SOLIDIFICATION PLANT

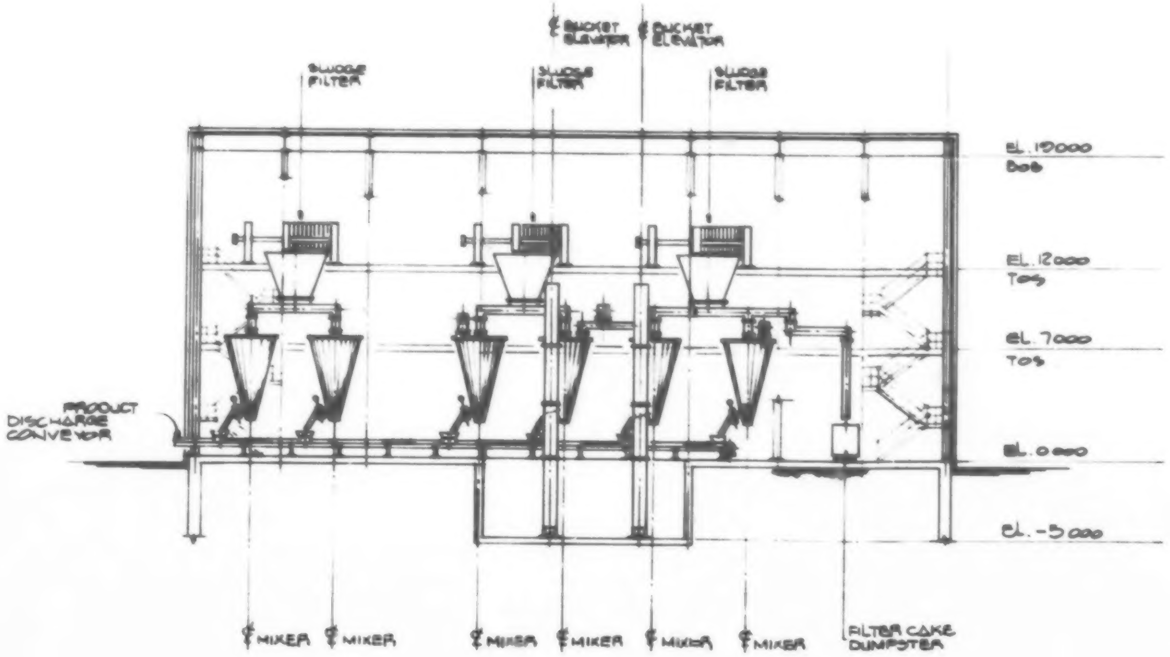
EQUIPMENT LAYOUT

PLAN


THIS DWG.
KEY PLAN


℄ VIBRATING SCREEN
℄ BUCKET ELEV.
℄ SLUDGE FILTERS
℄ CEMENT SILO
℄ CEMENT SILO
℄ CEMENT SILO
℄ CEMENT SILO
EL. 19 000 BOS
DUST WALL
EL. 13 500 BOS
EL. 12 000 TOS
EL. 7 000 TOS
OVERHEAD GRAB
K-5000 MIXER
EL. 0 000
DRY SOLID RESIDUES PIT
℄ CRUSHER
℄ PRODUCT DISCHARGE CONVEYOR
℄ TREATED LIQUID STORAGE TANK
℄ TREATED LIQUID STORAGE TANK
℄ TREATED LIQUID STORAGE TANK
℄ SODIUM SILICATE STORAGE TANK

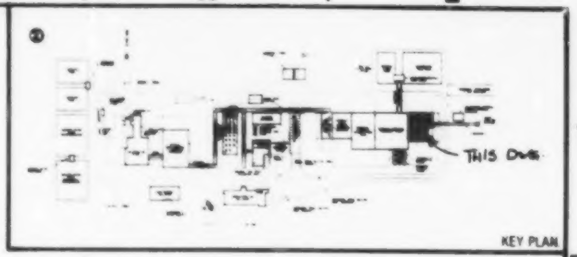
SECTION A-A

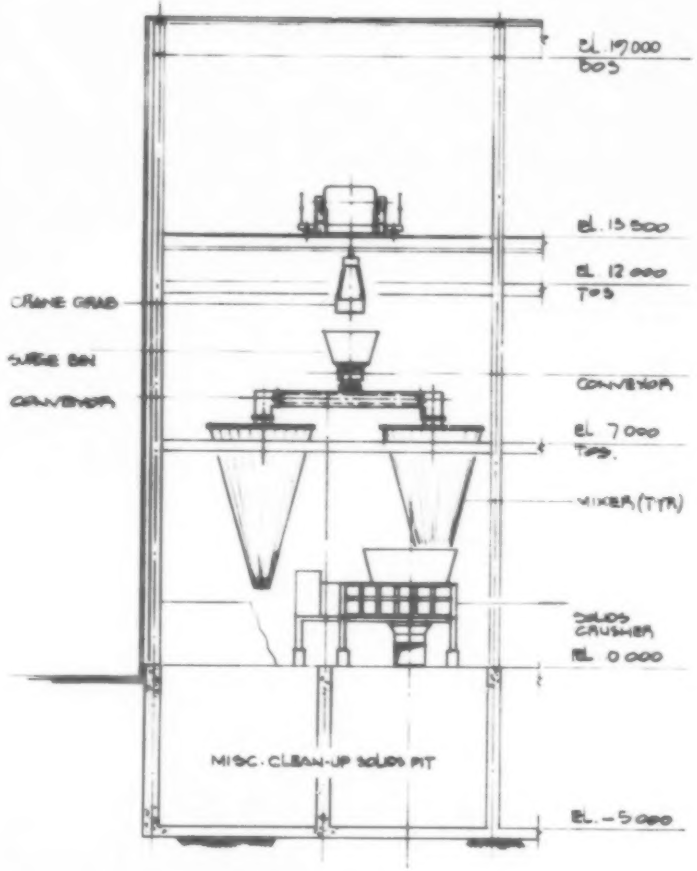

℄ BUCKET ELEVATOR
℄ BUCKET ELEVATOR
SLUDGE FILTER
SLUDGE FILTER
SLUDGE FILTER
EL. 15000 BOS
EL. 12000 TOS
EL. 7000 TOS
PRODUCT DISCHARGE CONVEYOR
EL. 0 000
EL. -5 000
℄ MIXER
℄ MIXER
℄ MIXER
℄ MIXER
℄ MIXER
℄ MIXER
FILTER CAKE DUMPSTER

SECTION B-B

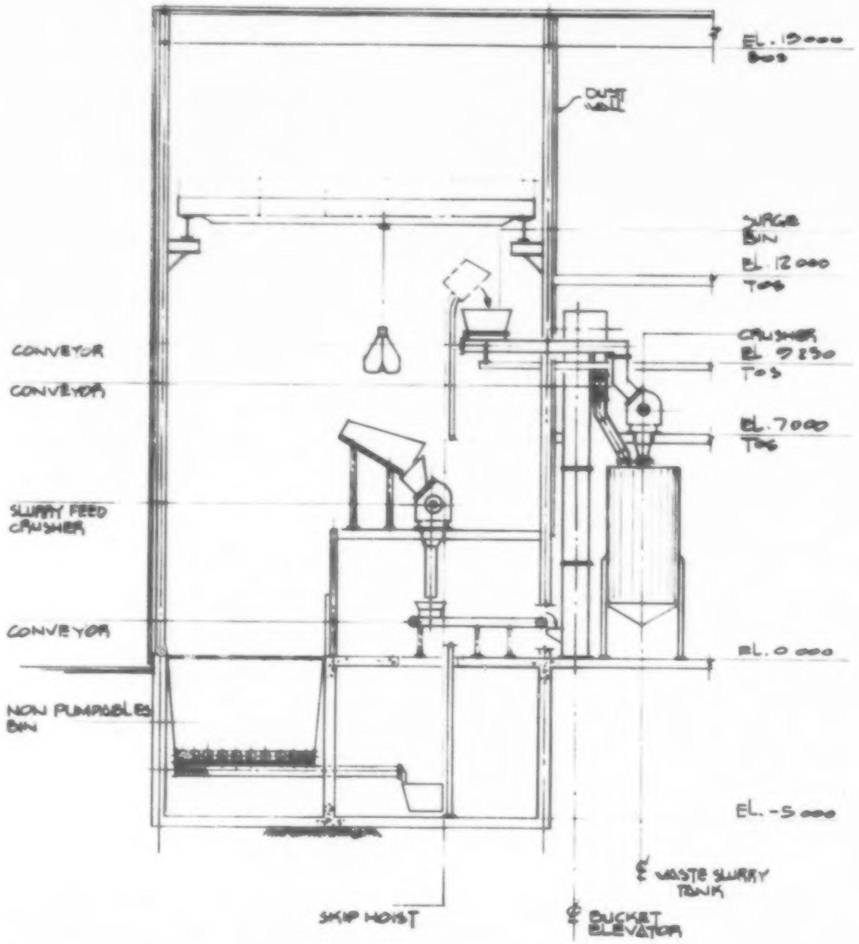
FIGURE 4

SOLIDIFICATION PLANT
CONCEPTUAL EQUIPMENT LAYOUT
SECTIONS


THIS DWG.
KEY PLAN


EL. 17000
BOS
EL. 13500
EL. 12000
TOS
CRANE GRAB
SURGE BIN
CONVEYOR
CONVEYOR
EL. 7000
TOS.
MIXER (TYP.)
SOLIDS
CRUSHER
EL. 0.000
MISC. CLEAN-UP SOLIDS PIT
EL. -5000

SECTION D-D


EL. 15000
BOS
DUST
WALL
SURGE
BIN
EL. 12000
TOS
CONVEYOR
CRUSHER
EL. 7250
TOS
CONVEYOR
EL. 7000
TOS
SLURRY FEED
CRUSHER
CONVEYOR
EL. 0.000
NON PUMPABLES
BIN
EL. -5000
℄ WASTE SLURRY
TANK
SKIP HOIST
℄ BUCKET
ELEVATOR

SECTION C-C

FIGURE 5

SOLIDIFICATION PLANT
CONCEPTUAL EQUIPMENT LAYOUT
SECTIONS

Inorganic wastes that require physical/chemical treatment prior to solidification, will be received in another live-bottom bin or in a concrete pit, if dry, from where they will be transported through dedicated size reduction equipment, to a slurry tank. The crushed waste will be slurried and pumped to the physical/chemical plant for treatment.

Three dewatering sludge filters of the physical/chemical plant are located above the row of mixers in the solidification plant. Filter cake from each of these sludge filters will be fed to either of two mixers by dedicated reversible conveyors located below each filter press.

The conveying/handling systems will be interlocked such that succeeding equipment items are operating before preceding equipment items can be started, in any particular system.

Liquid treatment residues that are pumpable will be received from the physical/chemical plant into storage tanks prior to processing in the low solids treatment system. Several storage tanks of appropriate capacity will be provided so that liquid residue batches of differing characteristics can be segregated for storage and treatment.

4.3.2 REAGENTS STORAGE AND HANDLING

The reagents that are required for solidification are Portland cement, (soluble) sodium silicate solution and additives such as lime, clay and flyash.

Portland cement will be delivered by trucks, each equipped with a blower to pneumatically convey the cement into storage silos located at the solidification plant. Portland cement will be transported pneumatically from the storage silos into the mixers of the high solids treatment system and/or the cement day hopper of the low solids treatment system. Motive air for pneumatic conveying will be provided by a blower adjacent to the storage silos and the return air will be vented to atmosphere through dust collectors associated with, and mounted on each storage silo.

Lime and flyash will also be delivered by trucks, each equipped with a blower and pneumatically conveyed to their respective silos. Fine powdered clay will be received in bags and emptied into a silo. Anticipated typical consumption of clay is about 1t per day. Plant demand for these additives will be satisfied by a common closed loop pneumatic conveying system to transport additives to the mixers of the high solids treatment system, similar to the Portland cement transport system. The additives will be added one at a time and minor cross contamination will not affect the processes.

Both the pneumatic conveying systems (for Portland cement and additives) will be self cleaning since the blower providing the motive air will be run for a few minutes after Portland cement or additive feed from the silo is stopped. The material in the ducting will be returned to the respective silo by the motive air via the dust collector associated with the silo.

Sodium silicate solution will be received in trucks, each equipped with a pump which will transfer the sodium silicate solution into storage tanks. Process demand for sodium silicate solution will be satisfied by a pumping system associated with the storage tanks.

Sufficient storage capacity for all reagents will be provided, taking into account the plant demand for the reagents and the lead time required for delivery of reagents from date of order, which in turn will be forecast based on the treatment schedule. Section 4.4.2.2 (p. 81) provides details of storage capacity.

4.3.3 HIGH SOLIDS TREATMENT SYSTEM

The storage and handling of the various high solids residues streams to the mixers has been described in Section 4.3.1 (p. 64). The handling and transport of reagents to the mixers has been described in Section 4.3.2 (p. 70).

Formulations will be determined in advance by laboratory treatability tests.

Solidification of a batch of high solids residue will commence by charging a mixer with a predetermined quantity of material. Addition of Portland cement and the appropriate additives in the correct proportions (as determined by the formulation) will be executed sequentially on a weight basis, as registered by a weight indicator. The mixers will be mounted on load cells and hence accurate quantities can be measured. Addition of small quantities of minor additives, when necessary, will be on a premeasured weight basis, at an appropriate point in the material conveying system. Process water, if necessary, will be added to the mixer in required quantities by means of flow measurement and control. An average of 30 minutes is anticipated to complete these loading operations for each mixer batch.

Complete and effective mixing of the contents is provided in the mixer. An average of thirty minutes is anticipated for the mixing stage.

The solidified material will be discharged from the mixer and conveyed out of the building for subsequent transport to the landfill. An average of thirty minutes is anticipated for the discharge operation.

Hence, an average of 90 minutes is anticipated for the loading of residues and reagents, for their mixing and for their discharge from the mixer.

The material handling systems are independent for each type of residue as stated earlier and hence simultaneous operation of mixers is possible. Each mixer will be capable of treating five batches per 8 hour shift although only four batches have been assumed for equipment sizing purposes. As the mixers are the major equipment item in this treatment system and equipment down time will result in loss of capacity, spare mixers are provided for the dry residue and wet residue processing duties, respectively.

The filter cake from each sludge filter can be processed in either of two mixers, thus providing adequate spare capacity. Flexibility is also provided in the physical/chemical plant to select any of the sludge filters to dewater a batch of treated waste.

Incineration residues will be treated by a dedicated solidification system situated at the incineration plant. This will obviate:

- the storage of residues over weekends, as the incineration plant will be in continuous operation, while the solidification plant will operate 5 days per week, and
- the transport and multiple handling of these residues which are prone to dust generation, thereby reflecting OWMC's desire to minimize risk to human health and impact on the environment.

This dedicated solidification system is similar to the high solids treatment system described earlier, consisting of two mixers. Residue solids from the incineration plant will be fed to either mixer by a conveyor on a continuous basis. When the residue capacity of the mixer is reached, the residue will be diverted to the other mixer. Portland cement, stored in a silo at the incineration plant, will be transferred pneumatically to the mixer, in the same way as in the solidification plant, in the correct proportion as determined by formulation. Process water and lime, available at the incineration plant will be added as determined by the formulation. Provision for storing and adding other minor additives will also be provided. The solidified material will be discharged from the mixer and transported to the landfill.

4.3.4 LOW SOLIDS TREATMENT SYSTEM

Pumpable inorganic treatment residues with low solids content will be treated in batches, drawing from the storage tanks in sequence.

Formulations will be determined in advance by laboratory scale treatability tests.

Solidification of a batch will commence by pumping the residue liquid from the storage tank to the mixing system at a constant flow rate. Addition of Portland cement in the correct proportion (as determined by the formulation) will be achieved by instrumentation that will control the ratio between the liquid and Portland cement. The Portland cement will be drawn from a day hopper and fed to a jet mixer at a predetermined rate by a weigh belt feeder. The residue and Portland cement will be mixed thoroughly in a mixing tank equipped with two high shear mixing agitators. From the mixing tank, the product pump will transfer the mixture to a pipeline mixer where sodium silicate will be added in the required proportion by a pump from the sodium silicate storage tank. This addition of sodium silicate in the correct proportion will be achieved by instrumentation that will again control the ratio between the residue liquid and the sodium silicate. Thus, once treatment of a batch starts, the process will be automatic until the entire batch is treated. The material from the pipeline mixer will be in a slurry form and will be delivered to the engineered landfill where it will set in place. Subsequent batches of residues will be treated in the same manner.

4.3.5 INSTRUMENTS AND CONTROL

The process control system for the solidification plant will be located in a central control room shared between the physical/chemical and solidification plants. The solidification plant operation will be controlled and coordinated from this central location, where the operator also has access to the data management system for treatment instructions, residue characteristics and solidified material characteristics (for quality control purposes). This ensures that operations within the solidification plant are co-ordinated in a safe manner.

However, limited local operation of the plant, with central coordination from the control room will be possible since provision will be made for the following:

- all mechanical equipment will have emergency stop buttons at the equipment,

- ability for local start and stop will be provided for all mechanical equipment,
- there will be limited grouping of local start and stop facilities to suit the relative locations/elevations of equipment,
- local indication/readout will be located where practical to suit local start/stop groupings,
- responsibility to "permit" local start will be at the control room, and
- interlock logic will be operable under both local and control room operation.

The grab crane will be operated from a cab located at a high elevation so that the pits that the crane grab is servicing can be visually monitored.

Control, process data acquisition and alarm annunciation will be handled by the process control system and functions will include:

- control of all process parameters,
- interlocks in the materials handling systems,
- process parameters indication,
- alarm annunciation, and
- process trend and alarm report generation.

All flows and levels which are controlled in the automatic mode, and indicating instruments which provide input to manual mode operation, are backed-up by pre-alarm and shut down systems to guard against malfunction of controllers and/or operator error.

4.4 SOLIDIFICATION PLANT OPTIMIZATION

This section examines how the conceptual design of the solidification plant has been optimized to achieve the capacity requirements and the treatment objectives that have been discussed in earlier sections of this report. Alternatives that are appropriate in terms of available equipment and their logical arrangement to store, handle and solidfy the anticipated residues will be discussed along with the rationale for selecting the proposed systems. Specific features which are designed to mitigate potential impacts on the environment are also highlighted in this section.

4.4.1 DESIGN CAPACITY

As stated under "Premises" (Section 2.4, p. 8), initially the solidification plant will be operated to treat inorganic residues resulting from 50 000 t/a of inorganic waste delivered to the Facility, in one shift/day, 5 days/week and 50 weeks/year. Multiple shift operation will enable processing of residues resulting from 120 000 t/a of inorganic waste delivered to the Facility.

Residues from the incineration of 30 000 t/a of organic waste delivered to the Facility will be solidified by a dedicated system located at the incineration plant.

Space will be provided at the solidification plant and at the dedicated system serving the incineration plant, for the installation of additional equipment/systems to enable treatment of inorganic residues resulting from 240 000 t/a of inorganic waste and 60 000 t/a of organic waste delivered to the Facility.

High Solids Treatment System

The high solids treatment system will be designed to treat 51 800 t/a of inorganic residues comprising solids and non-pumpables, irrespective of solids content, when the Facility is operating at its initial capacity of 120 000 t/a of inorganic waste as further illustrated on Table 3 (p. 63).

Capacity when operating a single shift for 5 days/week (5 shifts/week) and 50 weeks/ annum will be 21 600 t/a resulting from a feed rate of 50 000 t/a of inorganic waste to the Facility.

The design capacity of 51 800 t/a will be achievable by operating 12 shifts/week for 50 weeks/annum when the feed rate to the Facility is 120 000 t/a of inorganic waste. $\left(\frac{21\,600\text{ t/a} \times 12\text{ shifts}}{5\text{ shifts}} = 51\,800\text{ t/a}\right)$

By operating continuously for 24 hrs/day, 5 days/week, and the design margin that will be incorporated in the equipment sizing, the high solids treatment system will be capable of processing 100% more residues than the design feed rate for short periods to allow for wide variations in the physical mix of inorganic waste feed to the Facility (i.e. higher ratio of solid waste to liquid waste or higher solids content in the liquid waste). This flexibility will permit processing of treatment residues derived from a broad spectrum of wastes delivered to the Facility.

Dedicated System to Solidify Incineration Residues

This system will be designed to solidify 6 500 t/a of residues, comprising salt and ash, resulting from the incineration of 30 000 t/a of organic wastes. Since the incineration plant will be operated on a continuous basis (24 hours per day and 7 days a week), residues will result on a continuous basis, although the average rate is only about 1 t/h. Therefore, this system will be designed to receive the residues on a continuous basis, but solidify the residues in batches of a few tonnes each. Monitoring of this batch operation minimizes operator involvement at the incineration plant. The mixers themselves provide the buffer storage between continuous receipt of residues and batch-wise solidification.

Low Solids Treatment System

The design quantity of liquid residues requiring treatment in the low solids system is 21 600 t/a when the physical/chemical plant is operating at its initial capacity of 120 000 t/a of inorganic waste as further illustrated on Table 3 (p. 63). The quantity expected when the physical/chemical treatment plant is operating at 50 000 t/a on a single shift will be 9 000 t/a, or approximately 5 t/h.

Additional capacity will be provided for the solidification of the treated liquids from the physical/chemical plant, at a rate of up to 50 t/h, which is the design rate from the miscellaneous treatment system of the physical/chemical plant.

The low solids solidification system has therefore been sized for a design rate of 65 t/h, including margins.

This treatment capacity provides for a number of events including the possibility that the polishing treatment stage of the physical/chemical plant is shut down, internal effluent recycle demands are low due to incinerator plant shut down or if the treated effluent cannot be disposed of, for any reason. While this design basis may appear conservative, the flexibility of inorganic treatment at the Facility is significantly enhanced with only a small increase in cost due to larger pipeline diameter (from 50 mm to 100 mm) and larger pumps in this system.

The low solids system will be designed to operate 5 days/week for 50 weeks/annum. Daily operating time can be increased up to 24 hours, if necessary.

4.4.2 EQUIPMENT SELECTION AND SIZING

4.4.2.1 Storage of Residues

The quantities of residue that are expected to be solidified on an annual basis were identified in Table 3 (p. 63). From these quantities, an average daily rate of residue to be solidified has been determined for use as a basis for selecting storage requirements. In this context, it should be noted that waste arriving at OWMC's Facility will be pre-scheduled with the waste generators. This procedure will ensure that the waste batch can be successfully treated at the Facility, based on treatability tests on advance samples. It is therefore expected that under normal Facility operation, wide variations in quantity of waste delivered to the Facility can be avoided.

Sufficient storage is provided for inorganic and organic wastes delivered to the Facility at the physical/chemical and incineration plant areas, respectively. Hence, it is not necessary to provide large storage capacity at the solidification plant for residues resulting from treatment within the Facility.

Another factor that is relevant in the selection and sizing of storage equipment is that the solidification plant will initially need to operate only one shift of 8 hours/day. As the incoming waste quantity to the Facility builds up to a capacity of 120 000 t/a of inorganic waste, multishift operation will ensure that the required solidification capacity is achieved.

Based on the above, the minimum storage capacity for treatment residues has been selected to accommodate the average quantities expected for one week (5 day operation) when operating one shift/day. Additional storage capacity may be provided in the future based on the actual pattern of waste receipt at the Facility during the initial years of operation. Space for such expansion is provided in the plant layout.

The above approach is considered optimum, providing adequate flexibility in operations and minimizing initial investment.

Dry solid residues will be stored in a concrete pit (320 m^3). The pit will be divided into compartments to segregate the residues, if necessary, for separate solidification in batches.

Wet non-pumpable residues will be received and stored in two bins equipped with conveying screws at the bottom (live-bottomed bin). Two bins (60 m^3 each) are provided to enable segregation of non compatible batches of residues when necessary. The storage bins will be located in concrete pits, thereby providing two levels of engineered containment for these wet residues.

Some of the inorganic waste delivered to the Facility in solid form and/or as non-pumpable sludges may contain gross solids that need to be crushed to an average size of 2 mm, prior to being slurried and pumped to the physical/chemical plant for treatment. Provision is made to receive, store, crush and slurry such material within the solidification plant plot area, so that handling and size reduction of inorganic material can be confined to one area to limit dusting. A concrete pit (125 m^3) to store dry solid material and a live-bottom bin (50 m^3) to store non-pumpable sludges have been provided for this purpose.

It is also possible that the Facility will receive miscellaneous material resulting from clean up operations outside the Facility (e.g. chemical spills on highways resulting in contaminated soils). Such material may contain gross solids. The design provides for the receipt and storage of such material in one compartment of a concrete pit (250 m^3), along with the capacity to crush the material in an off-line, heavy duty crusher fed by the overhead crane, and storage of the crushed material in the second compartment of the concrete pit mentioned above. The crushed material will then be suitably treated at the Facility following treatability tests to confirm the treatment required.

As indicated on the layout plan of the solidification plant (Figure 3, p. 67), all of the storage pits and bins stated above have been located along one side of the solidification building, forming an aisle. Several alternative arrangements were studied and the above arrangement was selected as it provides:

- a common, segregated aisle at which the material can be unloaded from trucks transporting the material to the facility (up to 6 trucks can be unloaded simultaneously),

- the capability to transfer dry solid material to crushing and subsequent material handling equipment, from the pits with an overhead crane grab, servicing the common aisle, and

- the capability to contain any dust from the unloading, crushing and transfer operations in a small area by providing a dust wall that separates the storage and crushing area from the rest of the solidification plant. Dust collection from this small area can be accomplished in an efficient and cost effective manner.

This last point is of importance in minimizing both occupational risk and envirnomental impact resulting from fugitive dust emissions.

Liquid residues from the physical/chemical plant will be stored in tanks. The maximum flow rate of liquid residues from the physical/chemical plant is 55 t/h, as explained on page 78, where the design capacity of the low solids system is discussed. The storage capacity for liquid residues has been selected to accommodate the quantity that can be received from the physical/chemical plant in one shift, at this rate. Six tanks have been provided for this purpose, having a combined capacity of 390 m^3.

4.4.2.2 Storage of Reagents

The storage capacity for reagents such as Portland cement and soluble silicate has been selected to accommodate the quantity required for 5 shifts (as a minimum) when all treated liquid from the physical/chemical plant has to be solidified. This will provide adequate supplies between deliveries of the reagents during these peak demand conditions. When the plant is operating with normal flows, this provides storage equivalent to 15 shifts for cement and 40 shifts for soluble silicate. The storage capacity of cement under normal flows is lower than that for soluble silicate since cement is also required in the high solids system while soluble silicate is not.

Additives such as lime, clay and flyash are expected to be used sparingly and hence adequate capacity to store one truckload of each additive has been provided.

Dust collectors will be provided for, and on top of, every silo storing solid reagents that are in the form of fine powders, so that dust generated during filling and conveying of reagents is minimized, thus minimizing occupational risk to operators.

4.4.2.3 High Solids Treatment System

This system will solidify residues containing high solids in distinct batches. Solidification will be achieved in equipment which can facilitate complete mixing of the residues with the reagents and allow time for the solidification reactions to be established. Since the treatment batches comprise solids or high viscosity sludges or pastes, the type of equipment necessary to accomplish solidification are pug mills, cone mixers, cement mixers, plough mixers, etc.

A preliminary evaluation of these types of mixers suggests that cone mixers may be the appropriate type of mixer for the application envisaged. This will be investigated further during detailed engineering, based on detailed evaluation of equipment with specific suppliers and operating experience in similar applications at other facilities, before a final choice of mixer is made. The preliminary evaluation indicates that:

- the equipment is versatile and flexible when handling material with a wide range of physical characteristics (dry to wet paste to sludges) without sticking problems,

- the equipment is easy to operate and discharging the final mix is achieved by reversing the rotation of the motor driving the screw arm and screw,

- mixing is achieved quickly and effectively,

- processing of each batch can be accurately done as solid ingredients are added on a weight basis - the cone mixer is mounted on load cells,

- mixer construction is robust and operates with high on-stream availability in a variety of industrial environments, and

- the mixer provides high throughput capability for relatively low floor area and can also be used as additional buffer capacity for storing special batches of residues.

The main disadvantage of pug mills and other types of mixing equipment for this application is that they have a comparatively low static capacity for the required throughput, resulting in shorter mixing time for a given quantity of material. Hence they are less effective in ensuring that a large batch of material is mixed homogenously to produce a solidified material of uniform composition, when compared to cone mixers.

A closer examination of Table 3 (p. 63) indicates that the estimated quantity of treatment residues to be solidified originates from several sources and is fairly evenly distributed between the sources. It is therefore likely that there are variations in the characteristics of these materials that require different solidification formulations. Therefore, one mixer cannot be utilized to treat all the anticipated material at any given time. Further, the commercially proven and available size range of these mixers dictates that more than one cone mixer will be required for the quantity expected to be treated in this system.

The optimum size of mixers that have been selected enables each mixer to treat an average of 6.5 t of residue per batch, producing approximately 9.5 t of solidified material, the weight increase being due to the addition of reagents and process water (as needed). Each batch cycle takes an average of 90 minutes to process including initial charging of residue and final discharge of material. Hence, each mixer can treat 5 batches of residue per 8 hour shift. However, only 4 batches per shift are assumed to allow a margin for delays in loading, unloading or mixing operations.

Based on the above and the quantities of the various types of treatment residues to be solidified, the number of mixers required would be as follows:

o Dry solid residues from generators	1
o Wet non-pumpable residues from generators	1
o High solid residues from physical/chemical treatment	2
Total	4

Six (6) mixers have been provided in the design and arranged to receive residues such that:

- two mixers can process dry solid residues,
- two mixers can process wet non-pumpable residues,
- filter cake from each of the three filter presses of the physical/chemical plant can be processed in either of two mixers, and
- residue material from storage can also be transferred by the crane grab to any mixer via surge bins with feeders, which are at a level above the top of the mixers.

The above arrangement provides flexibility and sufficient design margin to allow for:

- variations in solids content of the waste feed to the physical/chemical plant which affects the total quantity of filter cake or high solid residues,

- variations in total feed to mixers for significant periods,

- situations where blending is not possible due to the special nature of residue batches and hence only partial batches are processed from time to time, and

- installed spare capacity.

During the conceptual design of the solidification plant, several alternative arrangements of the mixers were investigated. One main alternative (to the arrangement selected) was to arrange the mixers and the material handling systems such that each mixer could be charged with any of the residues by a common distributing conveyor. The main advantage of such an arrangement was that 5 mixers would have been adequate to provide the flexibility and design margin stated in the previous paragraph.

However, the main disadvantage of the arrangement was that reliance would have to be placed on the common distributing conveyor; i.e. if this conveyor failed or was out of service, the high solids treatment system could not be operated. The arrangement would also not be amenable to feeding material from the crane grab, via high level bin feeders, to the mixers. Another disadvantage of the arrangement was that the grouping of mixers into 2 rows of two mixers each with a fifth mixer in the middle resulted in a congested area above the mixers in terms of maintenance.

The selected arrangement, wherein the mixers are in a line, parallel to the aisle comprising the storage pits and bins, with dedicated material handling systems to feed each mixer, overcomes the disadvantage stated above, although it entails one additional mixer.

Similarly, two mixers are provided in the dedicated solidification system for processing incineration residues in a batchwise manner, thus allowing one mixer to be charged while the other is operating and to provide spare capacity.

The other components of the high solids treatment system comprise material handling and conveying equipment for residues, reagents and the solidified material. Separate storage and handling systems have been incorporated for dry solid residues, wet non-pumpable residues and filter cakes respectively, to ensure that:

- residues from different sources and exhibiting different physical characteristics are handled by the most appropriate equipment, and

- flexibility of operation is provided such that treatment can continue even if one mechanical system fails.

The design of the handling and conveying systems also ensures that small batches of residues having similar characteristics can, when appropriate, be charged into and blended in, the same mixer for solidification using the same formulation.

The sizing of the individual equipment in the various handling systems has been based on the throughput estimated in Table 3, with adequate design margins to cater to periodic variations in quantities.

The material handling systems are all enclosed to minimize dust generation and dust collectors are provided on storage silos so that dust during loading and conveying operations is contained. This reflects OWMC's desire to minimize risk to human health and impact on the environment.

4.4.2.4 Low Solids Treatment System

This system will process a batch of treated residues on a continuous basis at a rate of 65 t/h. This sizing has been selected to accommodate a rate of 50 t/h of treated liquids from the physical/chemical plant, and simultaneously process the design quantity of liquid residue from the physical/chemical plant.

Accordingly, feed pumps and piping for the liquid residues and soluble silicate have been sized for this capacity. The mixing system will provide a residence time in excess of 1.5 minutes to ensure complete mixing of the liquid residue and the reagents, at the design capacity. The cement weigh feeder and the product discharge pump have also been sized to accommodate this design capacity.

Turndown capability in this pumped system is good (30% of design capacity) for low capacity operation. Alternately, it is possible to operate for shorter periods at design capacity.

4.4.2.5 Reliability Requirements

The solidification plant comprises batch process(es) operating 5 days/week, and reliability requirements will be satisfied by ensuring the following:

- Selecting proven equipment that is proven and reliable for the duty specified.
- Adopting a good maintenance plan to ensure high availability during the 5 day/week operation (e.g. preventive maintenance).
- Standardizing on equipment where possible in order to minimize spares inventory.
- Providing adequate reserve capacity so that material inventory can be processed in a reasonable time without providing excessive storage capacity for feed materials.
- Providing installed (on-line) spares for equipment where down-time due to failure can be prolonged.
- Segregating the materials handling duty into more than one system so that the plant can still process material from another system if one system fails, (e.g. solid residue handling different from filtercake handling and from wet non-pumpable residue handling).

4.5 PLANT OPERATION

The following sections outline the solidification plant operating philosophies and safety features which ensure that the plant performs as expected and is capable of operating in a safe, environmentally sound manner during both normal operation and plant upset conditions.

4.5.1 OPERATING PROCEDURES

Figure 6 provides a schematic overview of the operating philosophy of the solidification plant. The key operating features of the plant are summarized below:

- The solidification plant will initially operate one - 8 hour shift per day, 5 days per week. Additional shifts will be worked as the waste quantities increase up to a maximum of 3 shifts per day, 5 days per week.

- In the event that a large volume of treated liquids from the physical/chemical plant cannot be discharged by evaporation and must be solidified, the low solids treatment systems will be operated continuously (24 h/d) until the liquid inventory is exhausted.

- Sample analyses and treatability testing will be carried out to establish treatment recipes for residues prior to solidification.

- Inorganic residues from the waste generator's facilities will be analysed to establish the need for physical/chemical treatment. If analysis indicates the need for physical/chemical treatment, the batch will be routed to the physical/chemical plant after size reduction (if necessary) and slurrying. If physical/chemical treatment is not required, the batch will follow the sequence of operations as for treated residues.

- Optimum solidification recipes, as established by treatability tests, will be used for the solidification of residues.

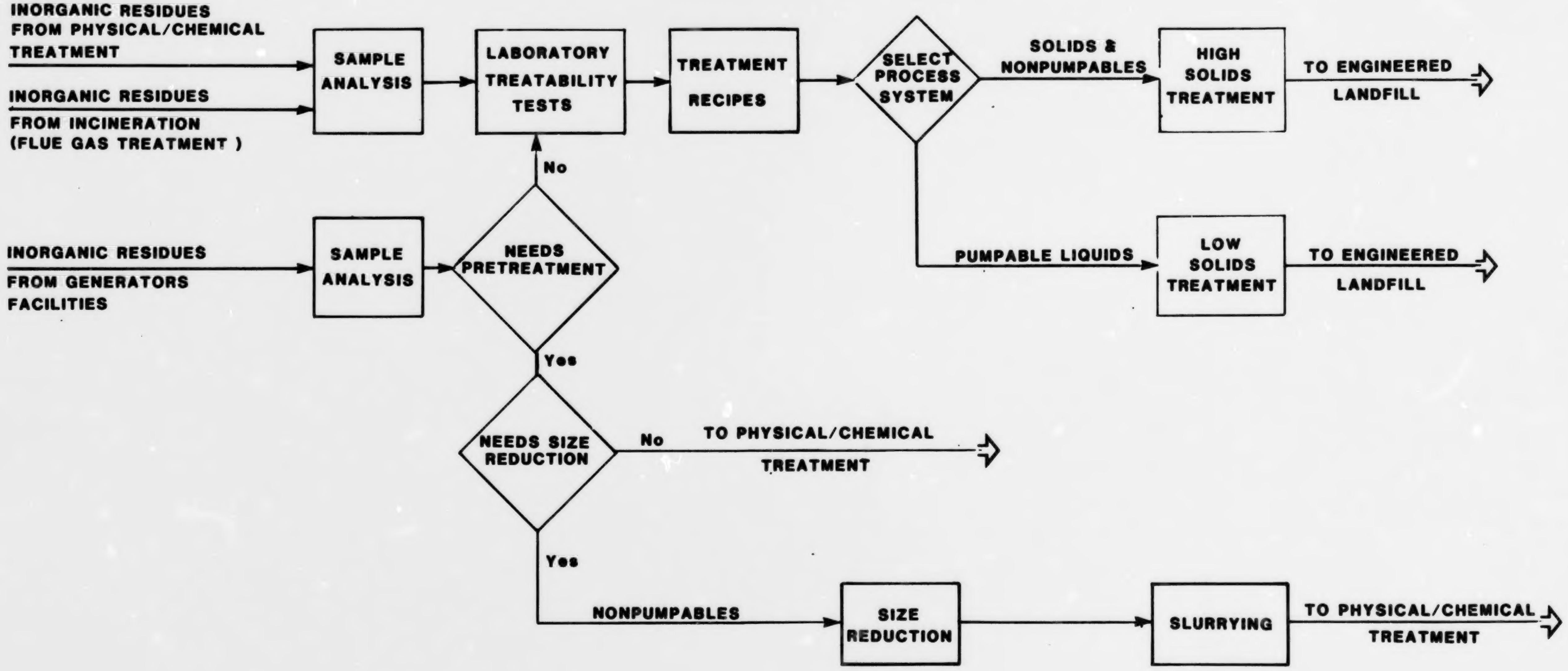

INORGANIC RESIDUES FROM PHYSICAL/CHEMICAL TREATMENT
INORGANIC RESIDUES FROM INCINERATION (FLUE GAS TREATMENT)
SAMPLE ANALYSIS
LABORATORY TREATABILITY TESTS
TREATMENT RECIPES
SELECT PROCESS SYSTEM
SOLIDS & NONPUMPABLES
HIGH SOLIDS TREATMENT
TO ENGINEERED LANDFILL
No
INORGANIC RESIDUES FROM GENERATORS FACILITIES
SAMPLE ANALYSIS
NEEDS PRETREATMENT
PUMPABLE LIQUIDS
LOW SOLIDS TREATMENT
TO ENGINEERED LANDFILL
Yes
NEEDS SIZE REDUCTION
No
TO PHYSICAL/CHEMICAL TREATMENT
Yes
NONPUMPABLES
SIZE REDUCTION
SLURRYING
TO PHYSICAL/CHEMICAL TREATMENT

FIGURE 6

SOLIDIFICATION PLANT
OPERATING PHILOSOPHY SCHEMATIC

- Based on the nature of the batch of residue, it will be solidified in the high solids system or low solids system.

- Quality control/checks will be carried out in accordance with the testing protocol established for the facility.

It is believed that the operational approach described above will provide a high level of confidence that wastes are being properly treated and the results of analytical tests on solidified material will verify that this is the case. In this manner, OWMC will be in a position to demonstrate that wastes are being treated in a manner which minimizes risk to human health, and impact on the environment.

Treatability Tests

The concept of performing bench scale treatability tests on advance samples of waste or residue prior to treatment is fundamental to the operation of the Facility. The characteristics of the waste and their treatment requirements will vary over a wide range and treatment at the Facility cannot be accomplished by a few standard methods for all the waste types anticipated.

Treatability tests on samples of each type of material will ensure that:

- the material will be subjected to the best combination of physical/chemical treatment steps followed by the optimum solidification of the treatment residues,

- batches of residues of similar characteristics can be blended prior to solidification, and

- the solidified material quality will meet OWMC's objectives, namely:
  - minimize risk to human health,
  - minimize environmental impacts, and
  - minimize financial costs to OWMC and the people of Ontario.

Significant operating experience will be gained during the initial years of facility operation and plant staff will become increasingly familiar with specific residue and waste types which may be of a repetitive nature. This will enable operators to call on their treatability data base for treatment formulations.

4.5.2 OPERATIONAL SAFETY FEATURES

Process Safety Features

- All treatment processes within the solidification building will be carried out in vessels which are totally enclosed. There will be no gaseous emissions during solidification treatment.

- Solid reagents will be stored individually in separate enclosed silos. In all cases fugitive dust is picked up by dust collectors before the air is discharged to atmosphere via roof vents.

- Liquid sodium silicate does not produce other fumes when storage tanks are being filled.

- The top inspection hatches on each mixer will remain closed during the treatment sequence.

- Alarms and shutdown systems will ensure that operating levels in storage tanks and silos are maintained and overflows are prevented. Similarly, excess flows in pumped and conveying systems will be prevented.

- Interlocks in conveying systems will ensure equipment items are operating in sequence and dumping of material to idle equipment will be prevented.

- The various feed streams to the solidification plant are either non-hazardous or have been treated already in the physical/chemical treatment plant to render them non-hazardous. Reagents to be used for solidification are also non-hazardous and have a long history of industrial use. No corrosive materials will be handled. The processes do not require high temperatures or pressures.

Power Failure

- o In the event of a power failure all motor driven equipment will stop. All filling valves on storage tanks and silos will fail closed, as will the control valves on the liquid feed lines and the soluble silicate feed line.

- o Pumpable liquid feed, as well as soluble silicate, can remain in the pipelines until power is restored. Cement and additivies can remain in the conveying ducts, as can materials in the conveying and handling systems, until power is restored.

- o In the high solids treatment system, a batch in a mixer can remain there even after addition of all solidification reagents as the set time is in the range of several hours, provided the power outage is temporary (less than one hour). If a prolonged power outage is anticipated, when mixers are in the mixing mode (all reagents have been added), the contents of such mixers will be dumped onto the concrete floor manually. On restoration of power, the batch can be returned to the mixer, if it has not solidified.

- o In the low solids treatment system, the treated liquid/cement mixture in the mixing tank will not harden for days since soluble silicate is added downstream of the low solids discharge pump. Hence, the contents of the mixing tank can be processed on resumption of power supply. If prolonged power outage is anticipated, emergency power supply will activate the mixing tank agitators, discharge pump and pipeline mixer so that the contents of the mixing tank are processed and discharged. The equipment and pipeline downstream of the mixing tank will then be cleaned with compressed air.

Ventilation

The following features are included to mitigate risk to human health and discharges to the environment:

- The area for storage and handling of dry solid and wet non-pumpable residues is segregated by a wall from the rest of the solidification building. Dust generated during unloading of these residues into storage and during transfer to crushing and handling equipment by the crane grab will be collected in a bag filter before the air is vented to atmosphere.

- The control room which is shared by the physical/chemical plant will be ventilated and air conditioned.

- The solidification building enclosing the treatment systems and reagent storage will be ventilated in accordance with normal industry practice.

Fire

- In common with the rest of the Facility, appropriate fire protection systems will be provided. It should be noted that none of the feed streams or reagents are combustible or explosive.

- The control room is protected by a Halon system.

Spills and Leaks

- Minor spills or leaks from storage tanks, pump seals or mixing tanks will be contained for clean up by curbing around the base of the equipment.

- Storage bins for wet non-pumpable residues will be located in concrete pits, thereby providing two levels of engineered containment for these wet residues.

- o Spillage resulting from a ruptured tank will be collected in segregated sumps also designed to collect floor washwater. Any such spills will be contained. Alarms will alert the operators that a spillage has occured.

Emergency Provisions

- o Escape routes from all levels of the solidification plant will be either via access stairways located at two strategic locations or via the physical/chemical treatment area.

- o Emergency eyewash and shower stations will be provided at strategic locations in the solidification building.

4.6 PERFORMANCE

Previous sections of this report have explained how technologies have been selected to meet OWMC's goals and planning principles. The approach adopted has been to select best available proven technologies and to optimize the design of the resultant solidification plant to attain the best containment of the residual contaminants in the solidified material. This section addresses the performance of the solidification plant.

The Portland cement based technology and the Portland cement/soluble silicate technology will be utilized for the solidification of the majority of treatment residues to be received by the solidification plant.

The design also provides the flexibility to utilize most of the other solidification technologies that were short listed, for the solidification of specific residues. This will permit the most appropriate technology to by employed, based on prior experience and the results of treatability tests.

4.6.1 PHYSICAL CHARACTERISTICS OF SOLIDIFIED MATERIAL

Utilization of the appropriate technology and optimized solidification formulations for each type of residue will ensure that the solidified material will have the following characteristics:

- The material will be physically stable and will not revert to the original liquid or sludge state. It will have the consistency of typical clay soils and good workability characteristics for placement in the landfill, after the initial curing.

- The time for initial curing can be varied to range from a few hours to about 2 days to suit the operating mode of the solidification plant and the landfill. For example, during daylight hours, when the landfill is in operation, the solidified material can be transported directly to landfill where it can be spread and compacted in a few hours. Solidified material that is produced when the landfill is not in operation, will be diverted to the interim storage building. The material will be reclaimed from the building and placed in the landfill when it is in operation. In such instances, the material will not be allowed to set hard so that reclaiming and handling is accomplished by standard mechanical equipment such as front end loaders.

- The material will develop good compressive (load bearing) strength characteristics which are expected to be retained indefinitely. Typically, the unconfined compressive strength will be over 1000 kPa.

- The material will have low permeability, similar to many natural clays. Typically, the permeability will be of the order of 10^{-7} to 10^{-8} meters/second.

4.6.2 CONTAINMENT OF CONTAMINANTS

The solidification plant will have the flexibility to use a range of reagents in ensuring that the most appropriate technology is employed in the solidification of treated residues, prior to landfill disposal. The operating philosophy will additionally ensure that optimum solidification formulations are used based on the results of treatability tests. In this manner residual contaminants of concern in the treated residues will be immobilized to the extent practical, thereby achieving one of the prime objectives for OWMC's solidification plant.

The immobilization, or containment, of contaminants in the solidified mass located in the engineered landfill will ensure that the concentration of contaminants in landfill leachate are minimized.

The prediction of leachate quality is a complex subject dependent on many factors including: type of waste, concentration and type of contaminants in the waste, method of pretreatment by incineration or physical/chemical treatment processes, solidification technology and formulation, and features of the engineered landfill. This subject is further addressed in the Facility Description Report (Ref: Monenco Limited [9]).

Standard methods have been established to test solidified materials in order to determine their hazardous classification. The standard Leachate Extraction Procedure prescribed in Regulation 309 by the MOE in Ontario (Ref: MOE[10]), is used to determine the hazardous classification of wastes by comparing the leachate quality so produced, with a standard list of contaminant concentrations which are derived from Ontario Drinking Water Objectives. This approach is similar to that adopted by the US Environmental Protection Agency.

Such tests are also used as an indication of contaminant immobilization, or containment, in determining the relative performance of different solidification technologies and formulations, in the treatment of specific wastes or residues.

The beneficial effects of solidification in containing contaminants within the solidified mass and thereby reducing the concentration of contaminants in leachate have been well demonstrated in published literature (see references) and are illustrated by the data on Table 4 (p. 98).

Certain contaminants are contained more readily than others in the solidified mass and the following paragraphs will place the performance of solidification technologies into perspective.

The data contained in Table 4 is compiled from a database assembled by Mr. J. R. Conner.

The first column of numbers in Table 4 lists the concentration of contaminants in the various wastes tested. The second column of numbers shows the concentration of contaminants in the leachate from solidification of wastes in each instance, wherein the leachate was produced by the USEPA Extraction Procedure, or by the Leachate Extraction Procedure prescribed by the MOE in Ontario. The last column of numbers lists the concentration of contaminants that are allowed in Ontario's Drinking Water Objectives (Ref: MOE[54]), as a basis for comparison.

Heavy Metals

The data presented in Table 4 illustrates how heavy metals can be effectively immobilized or contained, by solidification.

The extent of this containment can be optimized by appropriate pretreatment to render the metals in their most insoluble form, such as metal hydroxides and metal sulphides, and by the use of optimum solidification formulations.

TABLE 4
TYPICAL QUALITY OF LEACHATE FROM SOLIDIFIED WASTE

Contaminant	Concentration in Waste, mg/L (3)	Concentration in Leachate from Solidified Waste, mg/L (3)	Ontario Drinking Water Objectives, mg/L
HEAVY METALS			
Arsenic	58	0.005	0.05
	53	0.008	
	39.5	0.002	
Barium	10,000	0.12	1.0
	569	0.5	
	584	1.2	
Boron	593	2.5	5.0
Cadmium	49.5	0.62	0.005
	1.9	<0.0005	
	3,050	<0.016	
	222	0.08	
	4,310	0.08	
Chromium	1,750	0.1	0.05
	5,450	0.04	
	126	<0.01	
	2,000	0.12	
Copper	7,500	<0.02	1.0
	18,700	0.28	
	818	<0.03	
	2,440	0.43	
Iron	3,250	<0.03	0.3
Lead	14,430	0.04	0.05
	810	0.055	
	4,500	<0.1	
	7,950	<0.01	
Manganese	195	0.02	0.05
Mercury	100	<0.0003	0.001
	20,000	<0.0015	
	14	0.0017	
	7,630	0.00009	
Selenium(1)	78(2)	0.017	0.01
Silver	110	0.008	0.05

TABLE 4 (Cont'd)
TYPICAL QUALITY OF LEACHATE FROM SOLIDIFIED WASTE

Contaminant	Concentration in Waste, mg/L (3)	Concentration in Leachate from Solidified Waste, mg/L (3)	Ontario Drinking Water Objectives, mg/L
Zinc	63,000	0.04	5.0
	2,510	0.005	
	555	0.098	
	8,700	0.005	
SOLUBLE SALTS			
Chloride	96,850	13,100	250
Fluoride	3,900	50	2.4
	1,300	7.8	
Sulphate	48,000	2,387	500
ORGANICS			
Phenol	48	<0.1	0.002
PCB	18.8	<0.005	0.003
	68	<0.001	
	1.7	<0.0004	
Total Organic Carbon	28,000	8.2	5.0
Organic Nitrogen	686	<0.01	0.15
OTHER ANIONS			
Cyanide	1,000	0.08	0.2
	51,000	1.19	
Nitrate (N)	10,000	14	10
Nitrite (N)	320	<0.01	1.0

Note: (1) Data from solidified material taken from a landfill at West Thurrock in England.

(2) Concentration in digested sample of solidified mass from the landfill.

(3) All data from various published and unpublished literature sources.

It will be noted that for the contaminant concentrations in the particular wastes treated, the leachate produced using the standard extraction procedure compared favorably with Ontario Drinking Water Objectives. This is also the case for other anions such as cyanide, nitrites and nitrates.

Soluble Salts

Most salts of sodium and potassium are soluble in water, as are most chlorides and sulphates. Hence if these components are present in the residues that are solidified, they will not be contained very well in the solidified material and will be present in the leachate.

Table 4 includes the results of some recent solidification tests on waste containing significant quantities of chlorides and sulphates, and it will be observed that in this instance, the concentrations of these salts in the leachate exceed the Ontario Drinking Water Objectives by approximately 5 to 50 times for sulphate and chloride respectively.

These salts are not contaminants of concern and are present in abundance in the environment. Chlorides and sulphates are only listed in the Ontario Drinking Water Objectives under Table 2 - Parameters Related to Aesthetic Quality, with maximum concentration levels of 250 ppm and 500 ppm respectively.

Organics

While a considerable body of information is available in the performance of solidification technologies in the containment of inorganic contaminants, less is known on the performance of these technologies on organics.

This is mainly due to the fact that regulatory authorities have only recently started to address the need for criteria on organic species in the standard leachate extraction tests. Regulatory authorities such as the USEPA are now in the process of prescribing limits for organic contaminants, and it is expected that the Ministry of the Environment in Ontario will do likewise in the near future.

Organic species that are substantially insoluble in water can be tolerated to a larger extent than organic species soluble in water, in the solidified material, providing it is determined by treatability tests on samples, that the presence of the organic species do not interfere with solidification reactions.

Table 4 illustrates that for the limited number of wastes and organic species on which data is presented, a significant amount of containment is achieved in the solidified material.

OWMC's data base on organics is being expanded through a solidification test program being conducted at the Wastewater Technology Centre, Burlington, Ontario.

It is emphasized that control will be exercised over what is deposited in OWMC's landfill. If a residue is known (by analyses) to contain contaminants which would threaten the environment if placed in the landfill, then it will be incinerated to destroy organic species, prior to solidification or stored pending determination of an alternative safe disposal method.

It should be noted that the data presented in Table 4 are mostly based on tests where the raw wastes were solidified without optimum physical/chemical treatment prior to solidification. At OWMC's Facility, the objective of physical/chemical treatment is to alter the chemical form of these toxic contaminants to forms which are less toxic by virtue of the fact that they are either destroyed outright (such as cyanide) or converted into chemical compounds which have inherently low solubilities in water (such as metal hydroxides and metal sulphides) before solidification. The purpose of solidification is to subsequently ensure that these insoluble compounds are kept physically and chemically immobilized by further reducing the opportunity for these compounds to redissolve in water. Based on this, it is reasonable to expect better quality leachate than is shown in Table 4 for the specific contaminants listed therein.

4.7 SUMMARY

All materials that will be disposed of in OWMC's engineered landfill will be solidified, with the exception of slag from the rotary kiln incinerator.

The solidification plant incorporates the best available and proven technologies to solidify the wide range of treatment residues expected to be produced and received at OWMC's Facility. The design has been optimized to provide a high degree of flexibility, reliability and safety in:

- the receipt and handling of the wide range of material,
- solidifying the material in either the high solids treatment system or low solids treatment system, as appropriate,
- its ability to solidify materials in widely varying quantities by the inclusion of conservative design margins, multiple process units and installed spare equipment, and
- its capability to solidify treated liquid effluents from the physical/chemical plant for extended periods if the effluents cannot be otherwise disposed of, for whatever reason.

The design also provides for the planned and orderly expansion of the solidification plant compatible with the ultimate Facility capacity of 300 000 t/a.

The solidification of treatment residues utilizing the technology most appropriate for each type of residue, with optimum formulations, will ensure the best possible containment of inorganic contaminants of concern.

It is concluded that OWMC's solidification plant will complement the incineration of organic wastes and physical/chemical treatment of inorganic wastes, in ensuring that the solidified treatment residues disposed in the engineered landfill are both physically and chemically stable. It will ensure that the concentration of residual contaminants present in the landfill leachate is reduced to the lowest possible level, thereby minimizing risk to human health and impact on the environment.

REFERENCES

1. Ontario Waste Management Corporation, Facilities Development Process Phase 1 Report, Assembly and Analysis of Primary Information on Engineering, Environmental and Planning Issues, OWMC, September 1982. 41 pp., Appendices.

2. Generic Process Technologies Studies, The Proctor & Redfern Group, August 1982. 224 pp., Appendices.

3. Ontario Waste Management Corporation, Facilities Development Process Phase 3 Report, The Selection of Candidate Sites, OWMC, March 1984. 95 pp.

4. A. D. Little of Canada Limited, Rationale for the Selection of Technologies for Treatment and Disposal of Special Wastes in Ontario - July 1985.

5. Monenco Limited, Process Area Report - Incineration, 1986.

6. Monenco Limited, Process Area Report - Physical/Chemical Treatment, 1986.

7. Monenco Limited, Process Area Report - Engineered Landfill, 1986.

8. Monenco Limited, Process Area Report - General Facilities, 1986.

9. Monenco Limited, Facility Description Report, 1986.

10. Regulation 309, Ministry of the Environment, Ontario.

11. Ontario Waste Management Corporation, Facilities Development Process Phase 2 Report, Progress on the Selection of Facilities and Sites, OWMC January 1983. 38 pp., Appendices.

12. Waste Quantities Study, The Proctor & Redfern Group with Weston Designers - Consultants and Ontario Research Foundation, August 1982. 68 pp., Appendices. (Available from OWMC).

13. Leachability Comparison of Four Hazardous Waste Fixation Processes, Cote, P.L. and Hamilton, D.P., 38th Annual Purdue Industrial Waste Conference, West Lafayette, Indiana, May 1983.

14. The Solidification of Cement, Double, D.D. and Hellawell, A., Scientific American. pp. 82 - 90.

15. Alternative Nuclear Waste Solidification Processes, Heacock, H.W., Proc. Symposium on Waste Management, Tucson, Arizona, July 1975. pp. 177 - 206.

16. U.S. Patent #4,149,968, Kupiec, A.R., 1979.

17. Radioactive Waste Disposal by Hydraulic Fracturing, Laguna, W., Industrial Water Engineering, October 1970. pp. 32 - 37.

18. Guide to the Disposal of Chemically Stabilized and Solidified Waste, Landreth, R.E., U.E. Army Engineer Waterways Experiment Station, EPA-IAG-D4-0569, Cincinnati, Ohio, 1980.

19. Radiochemical Studies of Leaching of Metal Ions from Sludge Bearings Concrete, Mahoney, J.D. et. al., American Electroplating Society Research Project 49, 1980.

20. Solidification of High-Level Radioactive Wastes, National Academy of Sciences, U.S. Nuclear Regulatory Commission, Washington, D.C. June 1979.

21. Toxic and Hazardous Waste Disposal, Vols. I and II, Pojasek, R.B., ed, Ann Arbor Science Publishers, Inc., Ann Arbor, MI. 1979.

22. Design and Control of Concrete Mixtures, Portland Cement Association, Skokie, Illinois. 1979.

23. Disposal of By-Products from Non-regenerable Flue Gas Desulfurization Systems: Final Report, Rossoff, J. et. al. U.S. E.P.A. Report No. EPA-600/7-79-046. February 1979.

24. Everything You Always Wanted to Know About Portland Cement, Skolny, J. and Daugherty, K.E., ChemTech, January 1972. pp. 38 - 45.

25. Survey of Solidification/Stabilization Technology for Hazardous Wastes, U.S. Army Engineers Waterways Experiment Station, National Technical Information Service, Springfield, Va. 1979.

26. Current Technology in the Utilization and Disposal of Coal Ash, Clendenning, T.G. et. al., Ontario Hydro, Toronto. 1975.

27. Leach Testing of Chemically Stabilized Waste, Taub, I. and Roberts, K., a paper presented at the Third Annual Conference on Treatment and Disposal of Industrial Wastewaters and Residues, Houston, Texas. 1978.

28. Testing and Approvals, Information Bulletin 102, Stablex Corp., Radnor, Pa.

29. Leachate Testing of Hazardous Chemicals from Stabilized Automobile Wastes, McClelland, N.I., National Sanitation Foundation, Ann Arbor, Michigan, 1979.

30. Ultimate Disposal of Liquid Wastes by Chemical Fixation, Conner, J.R., 29th Annual Purdue Industrial Waste Conference, West Lafayette, Indiana. 1974.

31. Chemfix Data Package, Package I, Chemfix, Inc., Pittsburgh, Pa., 1972

32. Application of Second Generation Chemical Solidification/Fixation Processes to Iron and Steel Hazardous Waste Problems, Conner, J.R., 1983.

33. Chemical Fixation of Activated Sludge and End Product Applications, Conner, J.R. and Gowman, L.P., Proc. National Conference on Complete Water Rinse, New York. 1976.

34. The Use of Chemically Fixed Solids to Improve Sanitary Landfills, Conner, J.R. and Polosky, R.J., Chemfix, Inc., Pittsburgh, Pa. 1974,

35. Chemical Fixation and Solidification of Dredged Materials, Conner, J.R., Seventh World Dredging Conference, San Francisco. July 1976.

36. Disposal of Concentrated Wastes from the Textile Industry, Conner, J.R., December 1976.

37. Industrial Water Engineering, Conner, J.R., July/August 1977.

38. Testing of Chemically Solidified Waste for Disposal in Sanitary Landfills on On-Site Monofills, Conner, J.R., Proceedings of the Waste Stabilization/Solidification Workshop - Vegreville, AB. Alberta Environmental Centre, 1984, 259 p. AECV85-P1

39. The Modern Engineered Approach to Chemical Fixation and Solidification Technology, Conner, J.R., 1981.

40. A Critical Comparison: Ultimate Liquid Waste Disposal Methods, Conner, J.R., Plant Engineering. October 1972.

41. Chemical Interactions of Soluble Silicates in the Management of Hazardous Wastes, Falcone, J.S., Spencer, R.W.and Katsanes, E.P., The PQ Corporation, Lafyette Hill, Pa. 1982.

42. Chemical Stability of Metal Silicates vs. Metal Hydroxides in Ground Water Conditions, Gowman, L.P., Proc. National Conference on Complete Water Reuse, New York. 1976.

43. Flue Gas Desulfurization Waste Disposal Field Study at the Shawnee Power Station, Leo, P.O., et. al., Symposium on Flue Gas Desulfurization, Hollywood, Florida. November 1977.

44. Pollutant Potential of Raw and Chemically Fixed Hazardous Industrial Wastes and Flue Gas Desulfurization Sludges, Mahlock, J.L. et. al., U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., EPA-600/2-76-182. July 1976.

45. Applications of Soluble Silicates and Derivative Materials for the Management of Hazardous Wastes, Spencer, R.W. et. al., Research and Development. about 1982.

46. Customized Waste Stabilization, Waste Age. April 1981.

47. Transformation of Clay Minerals by Calcium Hydroxide Attack, Diamond, S. et. al., 12th National Conference on Clay and Clay Minerals. pp. 359 - 379.

48. Simulated Field Leaching Test for Evaluation of Surface Runoff from Land Disposal of Waste Materials, I.U. Conversion Systems. 1977.

49. An Assessment of a Process for the Solidification and Stabilization of Liquid Industrial Wastes, Ontario Ministry of the Environment, Ontario. 1976.

50. Report on Leachate Test Comparison Program, IU Conversion Systems, Inc., ASTM Subcommittee Section D-19.12.03 Meeting. November 1977.

51. Fly Ash as Fill and Base Material in Arkansas Highways, Thornton, S.I. et. al., Federal Highway Administration, PB-250 480. October 1975.

52. U.S. Patent #4,049,462, Cocozza, E.P. 1977.

53. Mineral By-Products, Pozzoline, Marietta, Georgia. 1984.

54. Ontario Drinking Water Objectives, Ontario Ministry of the Environment. 1983.

GLOSSARY OF TERMS

The following are definitions of special terms used in this report and are presented in alphabetical order.

BASIS OF DESIGN: The criteria on which the design of the treatment process or system is based, including incoming waste quantity and characteristics, treatment objectives, facility capacity, mode of operation, process reliability etc.

BINDER: The main component of a solidification formulation, which binds or cements together the components of the waste into a solid mass.

BLOWDOWN: That portion of the water or solution in the evaporator (evaporator blowdown) which is discharged in order to maintain the concentration of dissolved solids at predetermined limits.

CATALYST: A substance whose presence increases the rate of chemical reaction. Examples are lime and sodium silicate.

CEMENT: Generic term describing any inorganic material which fastens things together as it hardens.

CHEMICAL FIXATION/SOLIDIFICATION: Systems which not only chemically solidify the waste, but also render insoluble, immobilize, encapsulate, absorb or otherwise interact with selected waste components which are toxic or hazardous.

CONTAMINANT: Any solid or liquid chemical element or component individually or in combination which may:-

- impair the quality of the environment or the public therein for any use that can be made of it,
- cause injury or damage to property or plant or animal life,
- cause harm or material discomfort to any person,
- adversely affect the health or impair the safety of any person, or
- render any property or plant or animal life unfit for use by man.

CURING: The process in which chemical reactions cause the mixture of waste and solidification chemicals to develop its ultimate properties.

DETOXIFICATION: Treatment of materials to remove, immobilize or destroy toxic components.

EFFLUENT: Liquid streams resulting from complete physical/chemical treatment of wastes, unless otherwise qualified. Synonymous with Treated Effluent.

ENCAPSULATION: A technique of waste treatment involving isolation of the waste material by covering it with a jacket or membrane of impermeable, chemically inert material.

FLYASH: Particulate matter removed from combustion flue gases. Usual source is thermal power generating station.

GEL (GELATION): This is the first stage in the curing process. The waste transforms from a flowable condition to a non-flowable, self supporting condition but it is not very hard.

HARDEN: Synonymous with curing.

HYDRAULIC CONDUCTIVITY: The measure of the capability of a solid medium to transmit a liquid. In the context of this report, the liquid is water.

IMMOBILIZE: Retain the contaminant in the solid matrix thus preventing its mobility as when it is present in liquids. This reduces to a minimum its capability to leach or otherwise move into the environment.

LEACHATE: The liquid from a landfill resulting from water percolating through and picking up soluble contaminants en route. The percolating water is the leachant and the ability of the material to leach is called its leachability.

LIVE-BOTTOM BIN: A container which has screw conveyors at the bottom to enable discharge of pasty and/or sticky material stored in it.

MATRIX: The basic structure of the solid in which the unreacted waste constituents are embedded.

PERMEABILITY: The property of a solid material which allows a fluid to flow through it.

POLLUTANT: Synonymous with contaminant.

PORTLAND CEMENT: A specific cement made by heating a powdered mixture of clay and limestone to incipient fusion and then grinding to a fine powder. Use of the term in this report refers to Type I (general purpose) Portland Cement.

POLYMER: A substance composed of giant molecules formed by the union of a large number of simple molecules (Monomers). The process of forming a polymer is called Polymerization.

POZZOLANIC: A type of chemical reaction between a lime containing material and a siliceous or siliceous and aluminous material, which in themselves possess little or no cementitious value, but will chemically react to form compounds possessing cementitious properties.

PSEUDO-MINERAL: Solidified material which has properties of high stability, high melting point and a rigid friable structure similar to many soils and mineral deposits.

RESIDUE: Solids, semi-solid or liquid materials remaining after incineration of organic wastes and physical/chemical treatment of inorganic wastes, or as a waste product of other processes.

RETARDER: A substance whose presence decreases the rate of chemical reactions.

ROCK-LIKE (CONCRETE-LIKE): Solidified material which is very hard and is not workable in the landfill, obtained by adding more than the optimum quantity of solidification reagents.

SETTING: Synonymous with gellation (setting to a solid).

SETTING AGENT: A chemical which reacts with the binder and/or components of the waste itself to produce a solid, and without which the system would not function properly. e.g. sodium silicate in the Portland cement/ soluble silicate process.

SOIL-LIKE: A term to describe the working characteristics of solidified material which has properties similar to natural clay soils.

SOLIDIFICATION: The process by which chemically reactive formulations and components in the waste form stable solids which will not revert to the original liquid or semi-liquid state under conditions anticipated in the landfill.

SOLIDIFIED MATERIAL: The solid product resulting from the solidification of wastes and residues until it is deposited in the landfill.

SOLIDIFIED MASS: The solidified material after it has been placed in the landfill and fully set (cured).

STABILIZATION: The process by which liquid wastes are converted to non-flowing solids or gels, usually by non-chemical means (bulking), for the purposes of handling, storage, transportation or disposal in secure landfills. Stabilization is not expected to alter the hazard potential of the waste, especially with regard to toxicity.

SYSTEM: The assembly of equipment, piping, instruments, electrics, foundations and structures into an installation in which process treatment is executed.

TREATMENT: When used in connection with hazardous waste, means any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste or so as to render such waste less or non-hazardous, safer for transport, amenable for recovery, amenable for storage, or reduced in volume.

TREATMENT TRAIN: The combination of equipment and hardware arranged in a sequential manner to solidify waste residues and selected wastes. Synonymous with treatment system.

UCD WASTE CATEGORY: A numerical and descriptive designation referring to a system of classifying wastes developed at the University of California at Davis (UCD). Adopted by OWMC for its waste quantities studies.

APPENDIX A

TECHNOLOGY EVALUATION

APPENDIX A

This appendix should be read in conjunction with Section 3.3 Criteria for Technology Selection, which defines the criteria, weightings and how these criteria have been utilized in the evaluation of alternative technologies.

It may assist the reader to be aware that for brevity's sake, only those characteristics of a technology or system that play a role in determining its points score for a particular criteria, are included in the tables. This applies to all the evaluation criteria.

TECHNOLOGY EVALUATION

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Performance	20				
Most effective treatment	10	Will meet treatment objectives for a wide range of residues. (5) (50)	Will meet treatment objectives for a limited range of residues. (4) (40)	Will meet treatment objectives for a wide range of residues, but silicate addition is not required in all instances. In such instances, only cement will be used. (4) (40)	Will meet treatment objectives for a limited range of residues. (4) (40)
Efficiency: Energy Utilities Reagents	2	Most efficient for this application. (5) (10)	Requires 3 times more reagent than for Portland cement based process. (2) (4)	Efficiency is as good as for Portland cement based process. (5) (10)	Efficiency good for limited range of residues. (3) (6)
Solidified material characteristics	2	Good characteristics attained for a wide range of residues. (5) (10)	Good characteristics for a limited range of residues, but results in larger quantity of solidified material. (4) (8)	Good characteristics for a limited range of residues, as silicate addition is not required in all instances. (4) (8)	Good characteristics for a limited range of wastes where lime addition is essential. (4) (8)
Extent used elsewhere	6	Widely used since 1970. Over 1 million t solidified. (5) (30)	Used since 1974 by one organization (Stablex). Over 1 million t solidified but for limited range of wastes. (4) (24)	Used since 1974 by several organizations. Over 1 million solidified, of which about 200 000 t is high solids wastes. (4) (24)	Used since 1970, but not as extensively as Portland cement based process. (4) (24)
Sub Total - Performance		(100)	(76)	(82)	(78)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Performance	20				
Most effective treatment	10	Will meet treatment objectives for a limited range of residues. (4) (40)	Will meet treatment objectives for specific residues only. (2) (20)	Will meet treatment objectives for specific residues only. (2) (20)	Will only convert residues physically solid, by bulking. Very little reaction to detoxify or immobilize contaminants. (1) (10)
Efficiency: Energy Utilities Reagents	2	Efficiency good for limited range of residues. (3) (6)	Very high reagent requirements. (1) (2)	Very high reagent requirements. (1) (2)	Very high reagent requirements. (1) (2)
Solidified material characteristics	2	Good characteristics attained for a limited range of residues. (4) (8)	Not good consistently. Curing time is long. Large solidified material quantity. (2) (4)	Not good consistently. Curing time is long. Large solidified material quantity. (2) (4)	Poor. Curing time is very long. Very large solidified material qty. (1) (2)
Extent used elsewhere.	6	Used since 1970 but not as extensively as Portland cement based process. (4) (24)	Used since 1970 but for restricted applications. (3) (18)	Very restricted use for steel industry wastes. (2) (12)	Used by various waste management companies, but will have limited application in the future as it is not effective treatment. (2) (12)
Sub Total - Performance		(78)	(44)	(38)	(26)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Safety	**20**				
Occupational Risk	10	Uses minimum quantity of reagents. Hence minimal exposure to dust. (5) (50)	Larger reagent quantities, hence more exposure to dust. Flyash is also considered hazardous. (3) (30)	Uses minimum quantity of reagents, hence minimal exposure to dust. (5) (50)	In limited applications, as good as Portland cement based process. (4) (40)
Environmental Risk	10	Minimum landfill use, and trucking of reagents. (5) (50)	More landfill use and trucking of reagents. (3) (30)	Minimum landfill use and trucking of reagents. (5) (50)	In limited applications, as good as Portland cement based process. (4) (40)
Sub Total - Safety		(100)	(60)	(100)	(80)

TECHNOLOGY EVALUATION

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Safety	**20**				
Occupational Risk	10	In limited applications, as good as Portland cement based process. (4) (40)	Very large reagent use, hence more exposure to dust. (2) (20)	Very large reagent use, hence more exposure to dust. (2) (20)	Largest quantity of reagents used, hence maximum exposure to dust. (1) (10)
Environmental Risk	10	In limited applications, as Portland cement based process. (4) (40)	Greater landfill use and trucking of reagents. (2) (20)	Greater landfill use and trucking of reagents. (2) (20)	Maximum landfill use and trucking of reagents. (1) (10)
Sub Total - Safety		(80)	(40)	(40)	(20)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Flexibility	20				
Residue characteristics	7	Effective over a wide range of residue characteristics. (5) (35)	Effective over a limited range of residue characteristics. (4) (28)	Effective over a limited range of residue characteristics for high solids treatment. (4) (28)	Effective over a limited range of residue characteristics. (4) (28)
Residue quantities	7	Effective over a wide range as reagent addition is the least. (5) (35)	Effective over a limited range as reagent addition is high. (3) (21)	Effective over a wide range but silicate addition not required in all instances. (4) (28)	Effective over a wide range. Reagent addition marginally higher than Portland cement based process. (4) (28)
Rapid start-up/shutdown	6	Amenable to batch treatment, and rapid start-up and shutdown. (5) (30)	Amenable to batch treatment, and rapid start-up and shutdown. (5) (30)	Amenable to batch treatment, and rapid start-up and shutdown. (5) (30)	Amenable to batch treatment, and rapid start-up and shutdown. (5) (30)
Sub Total - Flexibility		(100)	(79)	(86)	(86)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Flexibility	20				
Residue characteristics	7	Effective over a limited range of residue characteristics. (4) (28)	Effective for specific residues only. (3) (21)	Effective for specific residues only. (3) (21)	Not flexible as it is only a bulking process. (1) (7)
Residue quantities	7	Effective over a wide range. Reagent addition marginally higher than Portland cement based process. (4) (28)	Effective for specific residues as reagent addition is very high. (3) (21)	Effective for specific residues as reagent addition is very high. (3) (21)	Not very flexible as reagent addition is very high. (3) (21)
Rapid start-up/shutdown	6	Amenable to batch operation, and rapid start-up and shutdown. (5) (30)	Amenable to batch operation, and rapid start-up and shutdown, but more batches need to be solidified due to large reagent addition. (3) (18)	Amenable to batch operation, and rapid start-up and shutdown, but more batches need to be solidified due to large reagent addition. (3) (18)	Amenable to batch operation, and rapid start-up and shutdown, but more batches need to be solidified due to large reagent addition. (3) (18)
Sub Total - Flexibility		(86)	(60)	(60)	(46)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Reliability	15				
Maintenance	1	Good, no special needs. (5) (5)	Good, no special needs. (5) (5)	Good, no special needs. (5) (5)	Good, no special needs. (5) (5)
Spare parts	2	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL			
Availability of reagents and spare parts	3	Very good. (5) (15)	Reagent quality can be variable from batch to batch, and hence could limit use. (3) (9)	Very good. (5) (15)	Very good. (5) (15)
Robustness of equipment	1	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Vulnerability to process upsets or breakdowns	8	Little vulnerability to upsets or breakdowns, as only one major reagent is used. (5) (40)	Controlled addition of reagents is important but upsets can be easily remedied in batch operation. (4) (32)	Controlled addition of reagents is important but upsets can be easily remedied in batch operation. (4) (32)	Controlled addition of reagents is important but upsets can be easily remedied in batch operation. (4) (32)
Sub Total - Reliability		(60)	(46)	(52)	(52)

TECHNOLOGY EVALUATION

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Reliability	20				
Maintenance	1	Good, no special needs. (5) (5)	No special needs, but larger mechanical items involved, due to larger reagent addition. (4) (4)	No special needs, but larger mechanical items involved, due to larger reagent addition. (4) (4)	No special needs, but largest mechanical items involved, due to larger reagent addition. (3) (3)
Spare parts	2	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Availability of reagents and spare parts	3	Very good. (5) (15)	Reagent quality variable. (3) (9)	Very good. (5) (15)	Reagent quality very variable. (2) (6)
Robustness of equipment	1	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Vulnerability to process upsets or breakdowns	8	Controlled addition of reagents is important but upsets can easily be remedied in batch operation. (4) (32)	Controlled addition of reagents is important but upsets can be easily remedied in batch operation. (4) (32)	Controlled addition of reagents is important but upsets can be easily remedied in batch operation. (4) (32)	Little vulnerability to process upsets or breakdowns. (5) (40)
Sub Total - Reliability		(52)	(45)	(51)	(49)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Operations	10				
Complexity	6		ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.		
Degree of automation	3	Easy operation with minimal attention. Can be automated to extent desired. (5) (15)	Easy operation with minimal attention. Can be automated to extent desired. (5) (15)	Easy operation with minimal attention. Can be automated to extent desired. (5) (15)	Easy operation with minimal attention. Can be automated to extent desired. (5) (15)
Start-up assistance	1	Good. (5) (5)	Poor. Licensor with best experience may want to operate plant themselves. (3) (3)	Good. (5) (5)	Good. (5) (5)
Sub Total - Operations		(20)	(18)	(20)	(20)

TECHNOLOGY EVALUATION

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Operations	10				
Complexity	6	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Degree of automation	3	Easy operation with minimal attention. Can be automated to extent desired. (5) (15)	High degree of operator attention required (slow reactions), despite automation. (3) (9)	High degree of operator attention required (slow reactions), despite automation. (3) (9)	High degree of operator attention required (slow reactions), despite automation. (3) (9)
Start-up assistance	1	Good. (5) (5)	May be limited due to lack of many specialist licensors. (3) (3)	May be limited due to lack of many specialist licensors. (3) (3)	May be limited due to lack of many specialist licensors. (3) (3)
Sub Total - Operations		(20)	(12)	(12)	(12)

TECHNOLOGY EVALUATION

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Commercial and Economic	10				
Restrictions on use	1	None. (5) (5)	Experienced supplier may not licence. (3) (3)	None. (5) (5)	None. (5) (5)
Cost	7	Most economical. (5) (35)	Average capital cost and operating cost. (4) (28)	Operating cost slightly higher than Portland cement based process. (4) (28)	Same as Portland cement based process. (5) (35)
Supplier competition and reliability	1	Good. (5) (5)	Not very good. Experienced supplier may not licence. (3) (3)	Good. (5) (5)	Good. (5) (5)
Delivery	1	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Sub Total - Commercial and Economic		(45)	(34)	(38)	(45)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Commercial and Economic	**10**				
Restrictions on use		None. (5) (5)	None. (5) (5)	None. (5) (5)	None. (5) (5)
Cost	7	Low capital cost but high operating cost. (3) (21)	Average capital cost and operating cost. (4) (28)	Very high operating cost. (1) (7)	Average capital and operating cost. (4) (28)
Supplier competition and reliability	1	Good. (5) (5)	Good. (5) (5)	No licensor known to be available. Generic process. (5) (5)	Limited competition. (3) (3)
Delivery	1		ALL TECHOLOGIES ARE JUDGED TO BE EQUAL.		
Sub Total - Commercial and Economic		(31)	(38)	(17)	(36)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Canadian Benefits	5				
Engineering	1	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Supply/fabrication of equipment	2	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Technology Transfer	2	Available. (5) (10)	May not be available, from experienced supplier. (3) (3)	Available. (5) (10)	Available. (5) (10)
Sub Total - Canadian Benefits		(10)	(3)	(10)	(10)
Grand Total		(435)	(316)	(388)	(371)

HIGH SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Canadian Benefits	5				
Engineering	1		ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.		
Supply/fabrication of equipment	2		ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.		
Technology Transfer	2	Available. (5) (10)	Available. (5) (10)	No licensor known to be available. Generic process available. (5) (10)	Available. (5) (10)
Sub Total - Canadian Benefits		(10)	(10)	(10)	(10)
Grand Total		(357)	(249)	(228)	(199)

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Performance	20				
Most effective treatment	10	Will meet treatment objectives for a wide range of residues. (5) (50)	Will meet treatment objectives for a limited range of residues. (4) (40)	Will meet treatment objectives for a wide range of residues. (5) (50)	Will meet treatment objectives for a limited range of residues. (4) (40)
Efficiency: Energy Utilities Reagents	2	Requires three times the quantity of reagents when compared with the Portland cement/soluble silicate process. (2) (4)	Requires about 6 times the quantity of reagents when compared with the Portland cement/soluble silicate process. (1) (2)	Most efficient for this application. (5) (10)	Requires three times the quantity of reagents when compared with the Portland cement/soluble silicate process. (2) (4)
Solidified material characteristics	2	Solidified material quality may not be consistently achieved with low solids residues. Results in larger solidified material quantity. (3) (6)	Solidified material quality may not be consistently achieved with low solid residues. Results in larger solidified material quantity. (3) (6)	Good characteristics attained for a wide range of residues. Not good for some specific residue types. (4) (8)	Solidified material quantity may not be consistently achieved with low solids residues. Results in larger solidified material quantity. (3) (6)
Extent used elsewhere	6	Widely used since 1970, but not as much as for high solids treatment. (4) (24)	Used since 1974 by one organization (Stablex) but not as much as for high solids treatment. (4) (24)	Excellent record in full scale application for low solids treatment. (5) (30)	Average, fairly restricted use, in this application. (2) (12)
Sub Total - Performance		(84)	(72)	(98)	(62)

TECHNOLOGY EVALUATION

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Performance	**20**				
Most effective treatment	10	Will meet treatment objectives for a limited range of residues. (4) (40)	Will meet treatment objectives for specific residues only. (2) (20)	Will meet treatment objectives for specific residues only. (2) (20)	Will only convert residues physically solid, by bulking. Very little reaction to detoxify or immobilize contaminants. (1) (10)
Efficiency: Energy Utilities Reagents	2	Same as Portland cement based. (2) (4)	Very high reagent requirements. (1) (2)	Very high reagent requirements. (1) (2)	Very high reagent requirements. (1) (2)
Solidified material characteristics	2	Solidified material quality may not be consistently achieved with low solid residues. Results in larger solidified material quantity. (3) (6)	Not good for low solids residues. Very long curing time. Very large quantities of solidified material. (1) (2)	Not good for low solids residues. Very long curing time. Very large quantities of solidified material. (1) (2)	Not good for low solids residues. Very long curing time. Very large quantities of solidified material. (1) (2)
Extent used elsewhere.	6	Average, fairly restricted use, in this application. (2) (12)	Average, fairly restricted use, in this application. (2) (12)	Average, fairly restricted use, in this application. (2) (12)	Average, fairly restricted use, in this application. (2) (12)
Sub Total - Performance		(62)	(36)	(36)	(26)

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Safety	20				
Occupational Risk	10	Larger reagent quantities, hence more exposure to dust. (4) (40)	Larger reagent quantities, hence more exposure to dust. Flyash is also considered hazardous. (3) (30)	Uses minimum quantity of reagents, hence minimal exposure to dust. (5) (50)	Same as Portland cement based process. (4) (40)
Environmental Risk	10	More landfill use and trucking of reagents. (4) (40)	Greater landfill use and trucking of reagents. (3) (30)	Minimum landfill use and trucking of reagents. (5) (50)	Same as for Portland cement based process. (4) (40)
Sub Total - Safety		(80)	(60)	(100)	(80)

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Safety	**20**				
Occupational Risk	10	Same as the Portland cement based process. (4) (40)	Very large reagent quantities and exposure to dust. (2) (20)	Very large reagent quantities and exposure to dust. (2) (20)	Very large reagent quantities and exposure to dust. (2) (20)
Environmental Risk	10	Same as for Portland cement based process. (4) (40)	Maximum landfill use and trucking of reagents. (1) (10)	Maximum landfill use and trucking of reagents. (1) (10)	Maximum landfill use and trucking of reagents. (1) (10)
Sub Total - Safety		(80)	(30)	(30)	(30)

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Flexibility	**20**				
Residue characteristics	7	Effective over a limited range of residue characteristics. (4) (28)	Effective over a limited range of residue characteristics. (4) (28)	Most flexible of all processes, for this application. (5) (35)	Same as Portland cement based process. (4) (28)
Residue quantities	7	Less flexible than Portland cement/soluble silicate process, due to larger reagent quantities. (4) (28)	Fair, due to larger reagent quantities than Portland cement based process. (3) (21)	Very flexible, requiring minimum reagent addition. (5) (35)	Same as for Portland cement based process. (4) (28)
Rapid start-up/shutdown	6	Amenable to batch treatment, and rapid start-up and shutdown. (5) (30)	Amenable to batch treatment, and rapid start-up and shutdown. (5) (30)	Amenable to batch treatment, and rapid start-up and shutdown. (5) (30)	Amenable to batch treatment, and rapid start-up and shutdown. (5) (30)
Sub Total - Flexibility		(86)	(79)	(100)	(86)

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Flexibility	20				
Residue characteristics	7	Same as for Portland cement based process. (4) (28)	Effective for specific residues only. (3) (21)	Effective for specific residues only. (3) (21)	Not flexible as it is only a bulking process. (1) (7)
Residue quantities	7	Same as for Portland cement based process. (4) (28)	Poor, due to very large reagent quantities. (2) (14)	Poor, due to very large reagent quantities. (2) (14)	Poor, due to very large reagent quantities. (2) (14)
Rapid start-up/shutdown	6	Amenable to batch operation, and rapid start-up and shutdown. (5) (30)	Amenable to batch operation, and rapid start-up and shutdown, but more batches need to be solidified due to large reagent addition. (3) (18)	Amenable to batch operation, and rapid start-up and shutdown, but more batches need to be solidified due to large reagent addition. (3) (18)	Amenable to batch operation, and rapid start-up and shutdown, but more batches need to be solidified due to large reagent addition. (3) (18)
Sub Total - Flexibility		(86)	(53)	(53)	(39)

TECHNOLOGY EVALUATION

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Reliability	15				
Maintenance	1	Good, no special needs. (5) (5)	Good, no special needs. However, larger mechanical equipment items involved, due to larger reagent addition. (4) (4)	Good, no special needs. (5) (5)	Good, no special needs. (5) (5)
Spare parts	2	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Availability of reagents and spare parts	3	Very good. (5) (15)	Reagent quality can be variable from batch to batch, and hence could limit use. (3) (9)	Very good. (5) (15)	Very good. (5) (15)
Robustness of equipment	1	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Vulnerability to process upsets or breakdowns	8	Little vulnerability to upsets or breakdowns, as only one major reagent is used. (5) (40)	Ratio control is important, can affect solidified material quality, but upsets can be remedied easily. (4) (32)	Ratio control is important, can affect solidified material quality, but upsets can be remedied easily. (4) (32)	Ratio control is important, can affect solidified material quality, but upsets can be remedied easily. (4) (32)
Sub Total - Reliability		(60)	(45)	(52)	(52)

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Reliability	15				
Maintenance	1	Good, no special needs. (5) (5)	Good, no special needs. However, larger mechanical equipment items involved, due to larger reagent addition. (4) (4)	Good, no special needs. However, larger mechanical equipment items involved, due to larger reagent. (4) (4)	Good, no special needs. However, larger mechanical equipment items involved, due to larger reagent addition. (4) (4)
Spare parts	2		ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.		
Availability of reagents and spare parts	3	Very good. (5) (15)	Reagent quality can be varied from batch to batch. (3) (9)	Very good. (5) (15)	Reagent quality very variable. (2) (6)
Robustness to process	8		ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL		
Vulnerability to process upsets or breakdowns	8	Ratio control is important but upsets can be remedied easily in batch operation. (4) (32)	Ratio control is important but upsets can be remedied easily in batch operation. (4) (32)	Ratio control is important but upsets can be remedied easily in batch operation. (4) (32)	Little vulnerability to upsets or breakdowns. (5) (40)
Sub Total - Reliability		(52)	(45)	(51)	(50)

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Operations	10				
Complexity	6	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Degree of automation	3	Automation is easy but operator involvement necessary. (4) (12)	Automation is easy but operator involvement necessary. (4) (12)	Easy operation with minimal attention. (5) (15)	Automation is easy but operator involvement necessary. (4) (12)
Start-up assistance	1	Good. (5) (5)	Poor. Licensor with best experience may want to operate plant themselves. (3) (3)	Good. (5) (5)	Good. (5) (5)
Sub Total - Operations		(17)	(15)	(20)	(17)

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Operations	10				
Complexity	6	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Degree of automation	3	Automation is simple but operator involvement necessary. (4) (12)	High degree of operator attention required (slow reactions). (3) (9)	High degree of operator attention required (slow reactions). (3) (9)	High degree of operator attention required (slow reactions). (3) (9)
Start-up assistance	1	Good. (5) (5)	May be limited due to lack of many specialist licensors. (3) (3)	May be limited due to lack of many specialist licensors. (3) (3)	May be limited due to lack of many specialist licensors. (3) (3)
Sub Total - Operations		(17)	(12)	(12)	(12)

TECHNOLOGY EVALUATION

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Commercial and Economic	10				
Restrictions on use		None. (5) (5)	Experienced supplier may not licence. (3) (3)	None. (5) (5)	None. (5) (5)
Cost	7	Average. (4) (28)	High. (3) (21)	Most economical. (5) (35)	Average. (4) (28)
Supplier competition and reliability	1	Good. (5) (5)	Not very good. Experienced supplier may not licence. (3) (3)	Good. (5) (5)	Good. (5) (5)
Delivery	1	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Sub Total - Commercial and Economic		(38)	(27)	(45)	(38)

TECHNOLOGY EVALUATION

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Commercial and Economic	10				
Restrictions on use		None. (5) (5)	None. (5) (5)	None. (5) (5)	None. (5) (5)
Cost	7	Average. (4) (28)	Very high. (2) (14)	Very high. (2) (14)	High. (3) (21)
Supplier competition and reliability	1	Good. (5) (5)	Good. (5) (5)	No licensor known to be available. Generic process. (5) (5)	Limited competition. (3) (3)
Delivery	1		ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.		
Sub Total - Commercial and Economic		(38)	(24)	(24)	(29)

TECHNOLOGY EVALUATION

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT BASED (PLUS MINOR ADDITIVES)	PORTLAND CEMENT/FLYASH	PORTLAND CEMENT AND SOLUBLE SILICATE	PORTLAND CEMENT/LIME
Canadian Benefits	5				
Engineering	1	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Supply/fabrication of equipment	2	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Technology Transfer	2	Available. (5) (10)	May not be available, from experienced supplier. (3) (6)	Available. (5) (10)	Available. (5) (10)
Sub Total - Canadian Benefits		(10)	(6)	(10)	(10)
Grand Total		(375)	(304)	(425)	(345)

LOW SOLIDS TREATMENT

SELECTION CRITERIA	WEIGHT	PORTLAND CEMENT/CLAY	LIME/FLYASH	LIME/CLAY	CEMENT OR LIME KILN DUST
Canadian Benefits	5				
Engineering	1	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Supply/fabrication of equipment	2	ALL TECHNOLOGIES ARE JUDGED TO BE EQUAL.			
Technology Transfer	2	Available. (5) (10)	Available. (5) (10)	No licensor known to be available. Generic process available. (5) (10)	Available. (5) (10)
Sub Total - Canadian Benefits		(10)	(10)	(10)	(10)
Grand Total		(345)	(210)	(216)	(196)

APPENDIX B

OPERATING COSTS COMPARISON

APPENDIX B

OPERATING COSTS COMPARISON

Operating costs for the processes in the short-list were calculated on the following basis:

- All costs are based on solidifying one tonne of inorganic residue and landfilling the resulting solidified material, and are in 1984 dollars (Canadian).

- The major contribution to operating costs are the cost of chemical reagents and landfilling of the solidified material.

- The utilities (power) and labour components of the operating cost are minor contributors and small differences between processes will not affect the comparison. Hence these costs are assumed to be constant for all processes, as a first approximation.

- When compared to reagent and landfilling costs, the amortization of capital costs is a minor contributor and differences between processes will not affect the comparison. Hence this cost component is also assumed to be constant for all processes.

- Reagent Costs: These were confirmed with major suppliers in Ontario and compared with prices in the U.S. The prices used in the calculations are listed below:

Reagent	Cost ($/t)
Portland Cement	100
Flyash	19
Lime	70
Sodium Silicate Solution	200
Clay	100
Kiln Dust (Cement or Lime)	28

- **Landfilling Cost**: High quality engineered landfill is currently priced in the northern U.S. at $60 - $100/t; a typical figure is $80/t. Capital and operating costs for such a landfill is approximately half of the market price, or about $40/t, which translates to about $57/t (Canadian). (A conversion factor of 1.29 Canadian dollars = 1.0 U.S. dollar was used.) Therefore, each % weight increase costs $0.57, in addition to the $57/t associated with the raw waste.

  Note: When the preliminary design of the Engineered Landfill is completed, the operating costs for OWMC's Landfill will be developed. The operating costs comparison will be reworked at that time, if unit landfill cost is different from above.

Table B.1 lists the reagent requirements, cost of reagents and cost of landfilling solidified material resulting from the solidification of one tonne of inorganic residue for low solids content and high solids content residues when employing each of the short-listed solidification processes.

Table B.2 shows the summarized operating costs for each of the processes.

From these tables, the real costs of the various solidification processes becomes evident. For low solids treatment, the Portland cement/soluble silicate process stands alone at about half the cost of the nearest competitor.

For high solids treatment, the Portland cement based, Portland cement/soluble silicate and Portland cement/lime are about equal. It can also be seen that if flyash is received at OWMC's Facility as a residue, at no cost, the Portland cement/flyash process becomes competitive.

TABLE B.1
COST RATING

Process	Cost Basis	% Weight Increase		$/Tonne of Waste - Low Solids Treatment		$/Tonne of Waste - High Solids Treatment	
	$/Tonne Of Reagent	Low Solids Treatment	High Solids Treatment	Chemical Cost	Landfill Cost	Chemical Cost	Landfill Cost
1. Portland Cement Based	100	100	20	100	114	20	68
2. Portland Cement/Flyash (1:3)	39	200	60	78	171	23	91
3. Portland Cement/Soluble Silicate (2.2:1)	137	33	20	45	76	27	68
4. Portland Cement/Lime (1:1)	85	100	25	85	114	21	71
5. Portland Cement/Clay (1:1)	100	100	35	100	114	35	92
6. Lime/Flyash (1:9)	24	300	100	72	228	24	81
7. Lime/Clay (1:4)	94	300	100	282	228	94	151
8. Cement or Lime Kiln Dust	28	250	100	70	199	28	85

TABLE B.2

SUMMARIZED OPERATING COST

Process	$/Tonne of Waste Low Solids Treatment	 High Solids Treatment
Portland Cement Based	214	88
Portland Cement/Flyash	249	114
Portland Cement/Soluble Silicate	121	95
Portland Cement/Lime	199	92
Portland Cement/Clay	214	127
Lime/Flyash	300	105
Lime/Clay	510	245
Cement or Lime Kiln Dust	269	113

The total solids present in a residue stream strongly affect the amount of solidification reagents used and hence the weight increase. The cost calculations presented earlier (Tables B.1, B.2) were based on average weight increase factors for low solids content in the range of 5 to 15% solids (weight) and high solids content in the range of 25 to 40% (weight).

To illustrate the effect of solids content on solidification/landfill costs, further data is provided in Tables B.3, B.4 and B.5 for the Portland cement based, Portland cement/soluble silicate and Portland cement/flyash processes.

TABLE B.3

Portland Cement Based

% Solids	Chemical Cost ($/t)	Wt. Increase %	Total Cost ($/t)
5	94	94	205
10	56	56	145
15	45	45	128
20	33	33	109
25	27	27	99
30	21	21	90
35	18	18	85
40	15	15	81
50 & higher	11	11	74

TABLE B.4

Portland Cement/Soluble Silicate

% Solids	Chemical Cost ($/t)	Wt. Increase %	Total Cost ($/t)
5	47	34	123
10	37	27	109
15	33	24	104
20	27	20	95
25	23	17	90
30	21	15	87
35	16	12	80
40	15	11	78
50 & higher	12	9	74

TABLE B.5

Portland Cement/Flyash

% Solids	Chemical Cost ($/t)	Wt. Increase %	Total Cost ($/t)
5	83	212	261
10	66	170	220
15	53	135	187
20	38	98	151
25	33	86	139
30	28	73	127
35	23	60	114
40	19	49	104
50 & higher	14	37	92

These results are consistent with the results shown in the Summarized Operating Cost Table B.2 , given the assumptions stated previously. Chemical cost and weight increase, with decreasing solids content. Total cost, from the 5% solids level to the 50%+ level, falls by factors of 2.8 for Portland Cement Based, 1.7 for Portland Cement/Soluble Silicate, and 2.8 for Portland Cement/Flyash.

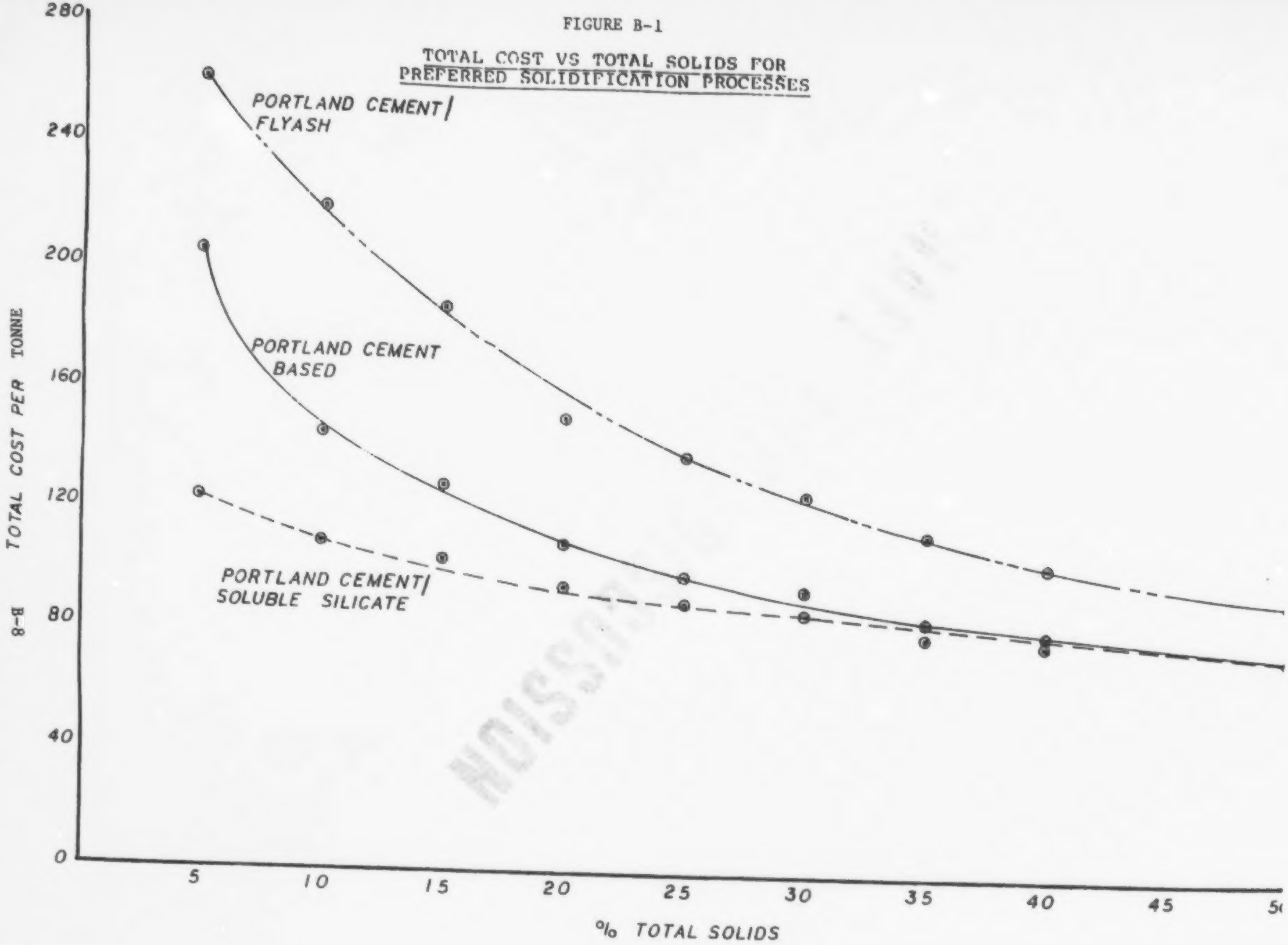
At high total solids, the Portland Cement Based and Portland Cement/Soluble Silicate processes have nearly identical costs. As the solids content falls, the Portland Cement/Soluble Silicate process becomes more cost-effective. The Portland Cement/Flyash process costs about 25% more than the Portland Cement Based process at all solids levels, and like the latter process, is much less cost-effective than the Portland Cement/Soluble Silicate process at low solids content.

The relationship of total cost as a function of total solids is presented in graphic form (Figure B.1) for the three preferred processes, for the data given previously. From these curves, the following conclusions can be drawn:

- The relationship between total cost (which in turn is directly related to the quantity of solidification chemicals added) and total solids in the residue is regular for all three processes i.e., the curves are smooth and fit the data points well.
- The Portland Cement/Soluble Silicate process total cost per tonne is least sensitive to fluctuations in total solids; the Portland Cement/flyash process total cost per tonne is more sensitive.

FIGURE B-1

TOTAL COST VS TOTAL SOLIDS FOR PREFERRED SOLIDIFICATION PROCESSES



APPENDIX C

SOLIDIFICATION PLANT INSTALLATIONS

APPENDIX C
SOLIDIFICATION PLANT INSTALLATIONS

TECHNOLOGY EMPLOYED: PORTLAND CEMENT BASED
(INCLUDING PORTLAND CEMENT/LIME AND PORTLAND CEMENT/CLAY)

ORGANIZATION	LOCATION	TYPE OF WASTES	CAPACITY (t/a)	TOTAL QUANTITY	YEARS OF OPERATION
Browning Ferris Industries Chemical Waste Management GSX (Formerly SCA Chemical) Other Central Treatment Sites	Landfill Sites Around the U.S.	Various Industrial	N/A	>1 000 000	Since 1970
NUS Corp. (Formerly Environmental Technology Co.)	Pittsburgh, Pa	Pickle Liquors and Sludges	N/A	N/A	N/A
			Reported to be installed as part of a central waste treatment facility in western Pennsylvania. This process now owned and supplied by NUS Corp.		
Fujisash Co. (Formerly described as Fujimasu Ind.) "Alset Process", supplied by Kenko Co., Ltd. in U.S. Portland cement plus fine-divided alumina setting agent.	Various Japanese cities, including Tokyo, Hirakata, Ohtsu, Kobe, Kita-Kyushu, Tsu, Hiroshima, Sakado, and Nagaoka.	Sewage sludge and industrial wastes (primarily sewage sludge)	720 000 t/a at Tokyo site alone	>5 000 000 t to date	1973 to present
TJK Inc. Takenake Sludge Treatment Process	Japan. Also, office in N. Hollywood, Ca, USA.	Sewage sludge and industrial waste.	Variable on a project basis.	> 60 000 cubic meters in 26 projects.	1973 to present

N/A: Not Available

APPENDIX C
SOLIDIFICATION PLANT INSTALLATIONS

TECHNOLOGY EMPLOYED: PORTLAND CEMENT/FLYASH

ORGANIZATION	LOCATION	TYPE OF WASTES	CAPACITY (t/a)	TOTAL QUANTITY	YEARS OF OPERATION
Stablex Corporation All plants now reported to have been acquired by other entities.	Blainville, P.Q.	Industrial	70 000	N/A	1983 to present
	Birmingham, U.K.	Industrial	200 000	80 000 t/a in 1977	1974 to present
	London (West Thurrock), U.K.	Industrial	400 000	30 000 t/a recently	1978 to present
	Japan - plants for Kanagawa Prefecture (Tokyo area) and Toyota (Nagoya area)	Industrial and Mixed	Originally scheduled to begin operation in 1979. No further information since that time.		
Industrial Waste Mgt. Enviroclean Process	Japan?	Industrial	N/A	N/A	N/A

APPENDIX C
SOLIDIFICATION PLANT INSTALLATIONS

TECHNOLOGY EMPLOYED: PORTLAND CEMENT/SOLUBLE SILICATE

ORGANIZATION	LOCATION	TYPE OF WASTES	CAPACITY (t/a)	TOTAL QUANTITY	YEARS OF OPERATION
Browning Ferris Industries	Houston, Texas Baton Rouge, La	Industrial	150 000	N/A	1974 to present
S.A.R.P. Industries	France	Industrial	50 000	N/A	1974 to present
Burlington Northern Railroad	W. Burlington, Iowa	Railroad Maint. Shop Sludge	5 000	N/A	1976 to present
AMAX Corp.	Climax, CO				
South Essex Water Pollution Control Plant	Salem, MA	Sewage Sludge with Industrial Waste	40 000	80 000 t	1984 to present
W.R. Grace Co.	Cambridge, MA	Organic Waste Filter Cake	20 000	N/A	1981 to 1983

APPENDIX C
SOLIDIFICATION PLANT INSTALLATIONS

TECHNOLOGY EMPLOYED: LIME/FLYASH

ORGANIZATION	LOCATION	TYPE OF WASTES	CAPACITY (t/a)	TOTAL QUANTITY	YEARS OF OPERATION
Conversion Systems Inc. (Industrial division is called Envirosafe Services)	11 Power Plants in the U.S.	SO_2 Scrubber Sludge	8 000 000 at present	75 000 000 t est 5 500 000 t up to 1978	1975 to present
	Honey Brook, PA	Industrial Waste	N/A	N/A	1980 to present
	Mountain Home, ID	Industrial Waste	N/A	N/A	(More than 3)
Chem-Met Services	Wyandotte, MI	Acids, Caustics Sludges, Oils and Paints	N/A	N/A	1966 to present
Stabatrol Corporation Purchased by Chemical Waste Management about 1980 or 1981; closed shortly thereafter. Terra-Tite Process.	Norristown, PA	Industrial	Closed now	>65 000 t	Mid-1970s to 1980 or 1981
Industrial Waste Mgt., Inc. Enviroclean Process	Japan?	Industrial	N/A	N/A	N/A
Chemlime Corp.	New Brighton, PA	Acids and Caustics	N/A	N/A	Since Early 1970s (Not known for how long)

APPENDIX C
SOLIDIFICATION PLANT INSTALLATIONS

TECHNOLOGY EMPLOYED: LIME/CLAY

ORGANIZATION	LOCATION	TYPE OF WASTES	CAPACITY (t/a)	TOTAL QUANTITY	YEARS OF OPERATION
Canadian Waste Technology Ltd. Licensed by Ontario Liquid Waste Disposal to Laidlaw Transport, Ltd. in 1976	Hamilton, Ont.	Industrial	125 000	>1 000 000 t	1976 to 1980

APPENDIX C
SOLIDIFICATION PLANT INSTALLATIONS

TECHNOLOGY EMPLOYED: CEMENT KILN DUST, LIME KILN DUST, AND MISCELLANEOUS

ORGANIZATION	LOCATION	TYPE OF WASTES	CAPACITY (t/a)	TOTAL QUANTITY	YEARS OF OPERATION
Browning Ferris Industries Chemical Waste Management GSX (Formerly SCA Chemical)	Processing and Landfill Sites Around the U.S.	Industrial	N/A (Very large)	>1 000 000 t	1970 to present
Envirite Field Services Formerly American Resources, Now part of Envirite Corp. Permix Process	Thomaston, CT York, PA Canton, OH Harvey, IL	Industrial	100 000 at Thomaston, CT	N/A	1976 to present at Thomaston,CT
Various Waste Generators and Waste Management Companies	Various in the U.S.	Industrial	N/A	>1 000 000 t	1970 to present

APPENDIX D

PROCESSES LISTED UNDER GENERIC TECHNOLOGIES

APPENDIX D
PROCESSES LISTED UNDER GENERIC TECHNOLOGIES

Technology	Processes	Country of Origin
PORTLAND CEMENT BASED		
	ATCOR	USA
	Browning-Ferris Ind.	USA
	CFS Systems	USA
	Chem-Nuclear	USA
	Ebara-Infilco	Japan
	Fujimasu Industries	Japan
	Hittman	USA
	NUS Corporation	USA
	Onoda Cement Co.	Japan
	Oak Ridge National Laboratories (U.S. Department of Energy)	USA
	Solid Tek Inc.	USA
	Stock Equipment	USA
	TJK Inc.	Japan
	TRW Corporation	USA
PORTLAND CEMENT/LIME		
	CFS Systems	USA
	Industrial Waste Management	USA
	Nu-Kem	Germany
	Onoda Cement Company	Japan
	Petrifix Process	France

APPENDIX D
PROCESSES LISTED UNDER GENERIC TECHNOLOGIES

Technology	Processes	Country of Origin
PORTLAND CEMENT/CLAY		
	CFS Systems	USA
	Environmental Technology Corporation	USA
	Oak Ridge National Laboratories (U.S. Department of Energy)	USA
PORTLAND CEMENT/SOLUBLE SILICATE		
	CFS Systems	USA
	ChemFix(TM)	USA
	Delaware Custom Material	USA
	French Atomic Energy Commission	France
	Fujibeton(TM)	Japan
	Kurita Water Industries	Japan
	Nippon Synthetic Chemical Industries	Japan
	United Nuclear Industries	USA
PORTLAND CEMENT/ALUMINATES		
	Alsite	Japan
SOLUBLE SILICATE BASED		
	Hitachi	Japan
	Japan Synthetic Chemical Company	Japan
	Progil	France
	Tyco	USA

Note: TM = Trade Mark

APPENDIX D
PROCESSES LISTED UNDER GENERIC TECHNOLOGIES

Technology	Processes	Country of Origin
PORTLAND CEMENT/FLYASH		
	Oak Ridge National Laboratories (U.S. Department of Energy)	USA
	Stablex (Seal-O-Safe)^{TM} *	England
LIME/FLYASH		
	Chem-Met Company	USA
	Conversion Systems	USA
	Stabatrol Corporation **	USA
	Research Cottrel	USA
	Willis and Paul	USA
LIME/CLAY		
	Canadian Waste Technology Ltd.	Canada
LIME BASED		
	Epes Lime	USA
	Sludgemaster$^{(TM)}$	USA
	Westestab	USA
CEMENT KILN DUST		
	Liqwacon	USA
	Wehran Engineering	USA

Note: * Now Part of the Rio-Tinto Group
** No Longer Active

APPENDIX D
PROCESSES LISTED UNDER GENERIC TECHNOLOGIES

Technology	Processes	Country of Origin
LIME KILN DUST		
	Mineral By-products	USA
FLYASH/CEMENT KILN DUST		
	Nicholson Realty Ltd.	USA
GYPSUM-BASED		
	Envirostone$^{(TM)}$	USA
THERMOPLASTIC		
	Werner & Pfleiderer (Bitumen)	Germany
	Southwest Research Institute (Sulphur-based)	USA
	Waste Chem (Bitumen)	USA
ORGANIC POLYMERIZATION		
	Washington State University (Polyester)	USA
	Chem-Nuclear Systems (Urea-formaldehyde)	USA
	Amefco (Urea-formaldehyde)	USA
	Hittman (Urea-formaldehyde)	USA
	NECO (Urea-formaldehyde)	USA
	Dow Polymer (Vinylester)	USA
	TRW Corporation (Polybutadiene)	USA
	Newport News Industrial (Urea-formaldehyde)	USA
	LSU	USA

APPENDIX D
PROCESSES LISTED UNDER GENERIC TECHNOLOGIES

Technology	Processes	Country of Origin
GLASSIFICATION		
	Battelle Pacific Northwest Laboratories	USA
	MSA Research Corporation	USA
GROSS ENCAPSULATION		
	TRW Industries	USA
MISCELLANEOUS		
	Soliroc(TM)	Belgium
	Calcilox(TM)	USA
	Fersona	USA